INCORPORATING STAKEHOLDER INPUT IN RESEARCH PRIORITIES FOR THE ALEUTIAN ISLANDS

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Abstract

Federal law requires that resource management agencies consider stakeholder input in the selection of preferred alternatives for proposed actions. Not only do stakeholders contribute unique perspectives on the impact of alternative actions and the desirability of various policy objectives, including stakeholders in the decision process adds to the perceived legitimacy of those decisions. Incorporating stakeholder input is legally required and advantageous to sustainable governance of the oceans and implementation of a National Ocean Policy such as ecosystem-based management. Agencies use a variety of formal and informal mechanisms to solicit and incorporate stakeholder input. In this study, we compare expert panel and stakeholder rankings of research and information needs in the Aleutian Islands region to see if stakeholder preferences are consistent with those of resource managers and experts when the analytical hierarchy process is used to prioritize those research and information needs. Normalized individual ratings were averaged across interest groups and compared to ratings averaged across all respondents. Spearman rank-order correlations were used to test the statistical significance of differences between groups and against the overall mean. Sensitivity analyses were used to check the robustness of the rankings across groups. We found a high level of association between rankings by an expert panel and rankings by stakeholders and little sensitivity to the make-up of stakeholders. These results suggest that the analytical hierarchy process can serve as a useful mechanism for organizing stakeholder input for environmental planning and resource management.

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Introduction

Essential steps in environmental planning and resource management include gathering, weighing, responding to and incorporating stakeholder input that is required under various federal laws including the National Environmental Policy Act (NEPA), the Magnuson-Stevens Fishery Conservation and Management Act (MSA), and the Endangered Species Act (ESA). Stakeholder engagement is a key component for sustainable governance of the oceans and for implementing National Ocean Policies, such as ecosystem-based management and coastal marine spatial planning (Costanza et al. 1998; Pomeroy and Douvere 2008; CEQ 2010; Halpern et al. 2012). However, processing stakeholder input can be challenging because of its large volume and the self-selection of contributors.

Although different definitions of "stakeholders" exist, we refer to stakeholders as those who have an interest in science, use, and management of marine resources (Pomeroy and Rivera-Guieb 2006; Mackinson et al. 2011). This definition includes interest groups, such as state and federal resource management agencies, non-governmental organizations, representatives of commercial enterprises, researchers at universities and other educational institutions, as well as the public. While environmental acts such as NEPA include procedures that allow stakeholder participation (Bronstein et

[1] Wadsworth, R.W., K.R. Criddle. 2012. Incorporating Stakeholder Input in Research Priorities for the Aleutian Islands. Prepared for submission to the North American Journal of Fisheries Management.

al. 2005), the influence of stakeholders in decision-making is often opaque. For example, resource management agencies often receive comments that express concern about the environmental, economic, and social impacts of projects, particularly those that may affect ESA listed species. Comments often include multiple copies of form letters, letters submitted on behalf of large numbers of signatories, and unique letters sent by individuals. State and federal agencies rely on a variety of methods to solicit, tabulate, categorize, and respond to comments. While agencies are required to take into consideration public comment, it is often unclear to the public if and how such input actually affects decisions. For example, does a large volume of comments from one interest group overly influence processes or decisions related to particular actions? Steelman (1999) noted that it is particularly difficult for agencies to respond to and incorporate value judgments expressed by stakeholders.

Established by the MSA, the Regional Fishery Management Council (RFMC) process is designed to encourage stakeholder participation in fisheries management. Members of stakeholder groups attend RFMC meetings and can provide input as written or oral testimony on agenda items. Although the meetings are open to all members of the public, studies on attendance levels suggested that those with a preference toward more extreme policies as well as those with less travel distance to meeting locations were more likely to attend (Turner and Weninger 2005; Brzezinski et al. 2010). RFMC voting members and their Advisory Panels and Scientific and Statistical Committees listen to testimony, but it is not always clear how stakeholder input affects decision-making or whether disproportionate weight is given to input from particular stakeholders.

Group decision-making techniques provide structured and transparent processes that incorporate expertise and value judgments from multiple participants. A common group decision-making approach involves a proposal of a problem, followed by an unstructured pooling of solutions and the final selection of a decision based on consensus or majority vote (Van De Ven and Delbecq 1974). However, that approach does not work well in the complex multi-objective frameworks common to natural resource management, nor does it satisfy the public notification and review requirements of NEPA or the Administrative Procedures Act (APA). Moreover, when multiple management agencies have overlapping responsibility for a particular resource they may have conflicting economic, social, and natural resource conservation priorities or objectives, and may receive incongruent input from different sets of stakeholders.

The analytical hierarchy process (AHP) is a group decision-making technique developed in the 1970s to provide a tool for solving discrete multiple criteria problems (Saaty and Kearns 1985; Saaty 2001). The AHP structures a problem into a hierarchy and evaluates group preferences through numerical rating to identify priorities among choices. Advantages for using the AHP include avoiding a "group-think" mentality and avoiding the tendency to overrule views that differ from those of the majority.

Applications of the AHP extend to almost all areas of decision-making including planning, conflict resolution, and prioritization in such areas as policy development, economics, engineering, medical, and military science (Vaidya and Kumar 2006). Within the last two decades, the AHP has been extended to natural resource decision-making such as fisheries (Schmoldt et al. 2001). Because natural resource managers often have to

make decisions in light of existing data gaps, numerical rating is useful as a method to incorporate quantitative (i.e., best available science) and qualitative (e.g., professional judgment) information into an analysis. Applications of the AHP to marine resource research and management show that multiple stakeholder groups can come to common agreement on priorities while highlighting conflicting opinions between groups. In evaluating management of the Chinook salmon, *Oncorhynchus tshawytscha*, recreational fishery on the Kenai River, Alaska, Merritt and Criddle (1993) found many commonalities in preferences across conflicting stakeholder groups. Although the groups disagreed sharply about allocation issues, they concurred on the desirability of many measures to enhance conservation and management and to increase funding for enforcement of regulations. Leung et al. (1998) surveyed members of the Western Pacific RFMC to evaluate alternatives for limiting entry of longliners in the Hawaiian pelagic fishery and found consistency in management choices across four bodies of the RFMC. Wattage and Mardle (2005) used AHP to evaluate stakeholder preferences towards wetland management in Sri Lanka and found a consensus for conservation among stakeholder groups.

The Aleutian Islands region provides an excellent opportunity to test decision-making tools, such as the AHP, because of overlapping and often conflicting demands for uses in the region and the need to work with multiple groups of stakeholders to coordinate research and management efforts. In order to coordinate research relevant to the Aleutian Islands region, it is necessary to begin by gathering, synthesizing, and prioritizing research and information needs.

The Aleutian Islands

The United States (U.S.) portion of the Aleutian Islands archipelago stretches more than 2,200 kilometers between Alaska and Russia, separating the Bering Sea from the rest of the North Pacific Ocean (Figure 1). The Aleutian Islands are a biologically diverse and productive ecosystem valuable for commercial and subsistence fishing as well as for supporting large seabird and marine mammal populations. Because the Aleutian Islands are located along the North Pacific great circle shipping route between East Asian and North American ports, the region is exposed to hazards posed by foundering vessels. This risk is anticipated to increase as marine transportation continues to increase in the region (TRB 2008).

The Aleutian Islands are a volcanic chain formed by the subduction activity of the North American and Pacific tectonic plates; they make up the northern boundary of the Pacific Ring of Fire. Channels between the islands form passes that allow the exchange of water between the Bering Sea, Gulf of Alaska and the rest of the North Pacific Ocean. Regional variations in oceanic currents, topography and geology influence marine species composition along the archipelago, with an ecological division occurring at Samalga Pass (Heifetz et al. 2005; Hunt and Stabeno 2005; Logerwell et al. 2005). Passes east of Samalga Pass are shallower with a broader continental shelf and are influenced by the Alaska Coastal Current, which is characterized by fresher, warmer and less nutrient rich water (Ladd et al. 2005). Characterized by colder, saltier and more nutrient rich water, the Alaska Stream influences the deeper passes west of Samalga Pass that include narrower continental shelves (Ladd et al. 2005). The Alaska Stream connects to the Aleutian North

Slope Current that flows eastward along the northern side of the Aleutian Islands. The western Aleutians Islands are largely of rocky substrate and have a high diversity and abundance of cold-water corals and sponges (Heifetz et al. 2005; Hunt and Stabeno 2005).

Although the region is remote and sparsely populated, the natural resources of the region are important for commercial fisheries and subsistence use. Currently, seven communities in the Aleutian Islands region are inhabited. These are False Pass, Akutan, Dutch Harbor/Unalaska, Nikolski, Atka, Adak, Attu; total population size is 5,864 persons (2010 Census). These communities are heavily dependent on commercial and subsistence fishing (Sepez et al. 2005); therefore, maintaining the health of marine resources is essential for maintaining ecosystem services that sustain the communities.

The Aleutian Islands region remains difficult to access and, consequently, significant data gaps exist for ocean-related research in the Aleutian Islands region. Recent fisheries closures have been imposed out of concern for the slow recovery of the endangered western distinct population segment of Steller sea lions in this region (NMFS 2010). Research reported in the 2005 special issue of *Fisheries Oceanography* provided insight into the biology, geography and oceanography of the eastern and central Aleutian Islands through an integrated ecosystem study (Schumacher and Kruse 2005; Stabeno et al. 2005). Also, a case was made for the need for an ecosystem services plan in the Aleutian Islands (Schumacher and Kruse 2005). The Aleutian Island Fisheries Ecosystem Plan (NPFMC 2007) assembled available information on the Aleutian Islands, conducted a risk analysis for various issues in the region, and provided a management tool to

specifically address the Aleutian Islands separately from the Bering Sea. A better understanding of the marine ecosystem that includes gathering appropriate scientific information is essential to properly manage and address future risks to the Aleutian Islands and to support ecosystem-based management.

Due to commonly adverse maritime weather conditions and proximity to valuable fishing grounds and sensitive wildlife refuge areas, the Aleutian Islands are vulnerable to oil and cargo spills that result from foundered vessels. Several accidents and spills have occurred in the region, including the grounding of the bulk carrier M/V *Selendang Ayu* in 2004 on Unalaska that spilled 336,000 gallons of heavy fuel oil and 60,000 tons of soybeans (TRB 2008). As a result, a committee empaneled by the Transportation Research Board of the National Academies developed guidance for conducting a comprehensive risk assessment for vessel accidents and spills in the Aleutian Islands (TRB 2008). Following these guidelines, the Aleutian Islands Risk Assessment Management Team (AIRAMT 2011) completed the first phase of the Aleutian Islands risk assessment. The second phase began in 2011 and will further evaluate and implement risk reduction measures recommended in the first phase. Improved knowledge necessary for safe and secure marine transportation is essential for the Aleutian Islands to address increasing risks.

Aleutian Island Regional Marine Research Plan (AI RMRP)

Initiation of the AI RMRP occurred after various research programs and management reports led to a call for national development of regional marine research plans (National Research Council 2000, U.S. Commission on Ocean Policy 2004). In

response to these reports, the National Oceanic and Atmospheric Administration (NOAA) provided funding to the National Office of Sea Grant, which issued a request for proposals in 2006 calling for the development of regional marine research plans. The National Office of Sea Grant solicited proposals from eight regions: the North Atlantic shelf, Southeast Atlantic, Caribbean, Gulf of Mexico, California Current, Alaska, Pacific Islands, and Great Lakes.

Because of the extent and diversity of Alaska's marine ecosystems, the Alaska Sea Grant program proposed development of a regional marine research plan focused on the Aleutian Islands region that would serve as a template for the future development of plans for other regions of Alaska. The Aleutian Islands region includes state and federal waters, and the federal exclusive economic zone surrounding the Aleutian archipelago, from Unimak Island to Attu Island (Figure 1). The model selected for the AI RMRP was a combination of a bottom-up and top-down approach that is similar to the approach adopted for the California Current regional marine research plan (Risien 2009).

The AI RMRP compiled and prioritized a list of management critical needs for the Aleutian Islands that represented shared concerns across a broad range of stakeholders. To address key interactions between society and the ocean, like other RMRPs, the AI RMRP focused on six national ocean research themes outlined in JSOST (2007). The six ocean research themes are: 1) *Improving Ecosystem Health*; 2) *Marine Transportation and Security*; 3) *The Ocean's Role in Climate*; 4) *Enhancing Human Health and Safety*; 5) *Stewardship of Natural and Cultural Ocean Resources*; and 6) *Increasing Resilience to Natural Hazards*. Stakeholders suggested research and

information needs under each of these themes and an expert panel ranked priorities using the AHP. Research priorities overlap between the themes and within themes, and therefore, complement and address each other. A report to the Alaska Sea Grant detailed the top twenty priorities for each ocean research theme (Wadsworth and Criddle 2012).

Study Purpose

In this study, we take advantage of information gathered to support development of the AI RMRP to explore the robustness of the research and information need priorities to the composition of the expert panel. We explore how different subsets of the expert panel would have assigned priorities to the research and information needs suggested by stakeholders. In addition, this study examines whether priorities assigned by the expert panel are similar to priorities that stakeholders would have assigned. We used Spearman rank-order correlation tests to compare normalized mean rankings across the research and information needs from the subsets of the expert panel and stakeholders. Rather than address all six ocean research themes included in the AI RMRP, we selected three for comparison: 1) *Improving Ecosystem Health*; 2) *Enhancing Human Health and Safety*; and 3) *Marine Transportation and Security*. We hypothesized that there would be statistically significant differences in rankings of these research and information needs because of the diverse interests and differing knowledge base of the expert panelists and stakeholders.

Methods

A variant of the AHP was used for ranking individual and group-means of the research and information needs. Typically, the AHP uses a pairwise comparison of choices; however, due to the large number of items to be ranked, pairwise choices were not practical[2]. In such circumstances, Saaty (1986) suggests that alternatives be scored against defined criteria. Following Merritt and Criddle (1993), respondents were asked to independently rate each category, sub-category, and research and information need. Data gathering took place in a three phase process that included stakeholder scoping, followed by expert panel opinion, and finally a stakeholder input and prioritization process. After review of the survey methods, the Institutional Review Board (IRB) granted an exemption for this research in 2010 Appendix (A1) and in 2011 Appendix (A2).

Stakeholder scoping

The initial phase of the AI RMRP, which provides background information for this study, consisted of a scoping process to collect a breadth of perceptions relating to management-critical research and information needs. From January to April 2008, paper and web-based questionnaires were used to gather stakeholder input for the six ocean research priorities plan themes. Research needs were defined as requiring the discovery of new knowledge about coastal and ocean processes and resources. Information needs were defined as requiring the synthesis or translation of existing knowledge. Responses were received from representatives of state and federal resource management agencies

[2] The number of pairwise comparisons is $\frac{1}{2}n(n-1)$, where n is the number of items to be compared. Thus, comparisons of research and information needs suggested by stakeholders would have entailed 49,141 pairwise comparisons. At four comparisons per minute, this would have taken respondents over 200 hours.

(agencies), non-governmental organizations (NGOs), individuals engaged in the fishing and processing sectors (fishing), community development corporations, local governments, university faculty and students (academic), members of Alaska native organizations, and the public at large. A majority (52%) of stakeholders did not specify an affiliation; 17% indicated affiliation with NGOs; 14% self-identified as academics; 9% self-identified as government agency employees; and 8% identified themselves as members of the fishing industry.

Input from 118 individual and group respondents provided over 1,000 suggestions of research and information needs across the six themes. The raw responses were consolidated to eliminate redundancies and responses that called for actions outside the scope of this project were dropped from consideration. The final list of 314 research and information needs was organized for each ocean research theme using a hierarchical structure, with categories at the top representing the broad topic areas, with sub-categories representing more specific topic areas, and with specific research and information needs listed under their corresponding sub-categories. An expert panel was assembled to rate hierarchy levels for the ocean research themes.

Expert panel

To begin the expert panel rating process, a workshop was convened in Anchorage on July 15 and 16, 2008. The panelists included 18 professionals and interested persons of varying expertise across the themes. Panelists were nominated by members of an Aleutians Ecosystem Forum (now named the Alaska Marine Ecosystem Forum), organized by the North Pacific RFMC. Panelists were chosen by their organizations as

representatives. The panel included eight agency personnel, three academics, three NGO representatives, and four individuals from the fishing and processing sectors.

Panelists rated the level of importance of each research and information need on a scale of one through nine, with one indicating a low level of importance, and nine indicating a high level of importance. Panelists developed a set of six criteria to use as guidance for rating each category, sub-category, and research or information need. The six criteria developed were: (1) the lack of information jeopardizes the ability to ensure sustainable development, management, or use of the resource (e.g., endangered or threatened species status, sentinel species, keystone species); (2) feasibility and cost effectiveness; (3) probability that research will successfully address a need; (4) information aids a broad swath of people (e.g., maintains and enhances human benefits); (5) there is a sequential order, whereby one need must be addressed before research can begin on another; and (6) there is a potential for synergy (i.e., research projects will address multiple missions and encompass multiple disciplines).

By the end of the 2008 workshop, priorities had been determined for categories and sub-categories of theme (1) *Improving Ecosystem Health*, and priorities for research and information needs of theme (3) *Marine Transportation and Security* were completed. On July 12, 2010, the original workshop participants with one replacement were contacted and asked to complete a web-based survey for prioritizing sub-categories and research or information needs under the *Improving Ecosystem Health* theme. This was followed up on September 15, 2010 with a link to a survey on research or information needs under the *Enhancing Human Health and Safety* theme and, on November 22, 2010,

with a link to a survey on research or information needs under the *Marine Transportation and Safety* theme. Because panel members were not in the same location, they were unable to discuss ratings for each survey question. Thus, the method used is most properly described as a variant of the group decision process typically used in the AHP. In April 2011, the results were presented to expert panel members via email and they were encouraged to review and perhaps reconsider their individual ratings in light of ratings assigned by other panelists. Panelists were asked to pay particular attention to research and information needs where there were large differences in scores, but were advised that consensus was not required. The resulting prioritized research and information needs are detailed in Wadsworth and Criddle (2012).

Stakeholder survey

We selected three of the six themes (*Improving Ecosystem Health*, *Enhancing Human Health and Safety*, and *Marine Transportation and Security*) to explore similarities and differences in prioritization of research and information needs by the expert panel and those of a cross-section of stakeholders. These three themes were selected to represent a range of research needs in the Aleutians, and to gather input from a range of interest groups that were interested in different topic areas. In April 2011, links to web-based surveys for the three themes were sent to the stakeholders who originally suggested research and information needs in 2008; this included 51 individuals who had provided email addresses on original surveys. From July to November 2011, the links were sent to fisheries, environmental and marine electronic mailing lists, officers of interest groups, and individuals with knowledge in the topics of each ocean research

themes. Each person contacted was encouraged to forward the survey links to other interested persons. We attempted to represent the range of stakeholder groups reflected in the expert panel, including agency personnel, academics, NGOs, and individuals and organizations engaged in the fishing and processing sectors. On September 2011, a draft of the AI RMRP report (Wadsworth and Criddle 2012) was presented in a public seminar in Dutch Harbor/Unalaska and attendees were encouraged to participate in the web-based surveys. In this study, we refer to respondents to the web-based surveys as *stakeholders*.

All survey forms included the list of criteria developed by expert panel participants for consideration when rating survey questions. Surveys provided respondents with the opportunity to comment on research or information needs that they considered already addressed and to suggest additional research or information needs. Incomplete responses were excluded from the analysis, although comments from those participants were saved.

Analysis

Because the ratings are subjective and because individual's ratings may be consistently high or consistently low across all research and information needs, ratings from each panelist were normalized. Normalized ratings were calculated using:

$$(1) \qquad y^*_{ik} = \frac{y_{ik} - \bar{y}_i}{s_{y_i}} \bar{s} + \bar{y},$$

Where y^*_{ik} is the normalized rating assigned by individual i to the k-th category, sub-category, or research and information need, $\bar{y}_i$ is the geometric mean for that individual's

ratings for all questions in a survey, s_{y_i} is the standard deviation for that individual's ratings for all questions in a survey, $\bar{s}$ is the arithmetic mean of s_{y_i} for all survey participants, and $\bar{y}$ is the arithmetic mean of $\bar{y}_i$ for all survey participants.

The geometric mean was used in the normalization formula because survey ratings were slightly skewed to the right. The weighted mean rating for each hierarchy level (i.e., category/sub-category/research or information need) in a theme was calculated using:

$$(2) \qquad W_k = \frac{\overline{y^*_k}}{\sum_k^N \overline{y^*_k}},$$

where W_k is the weighted mean of all normalized ratings for the k-th category, sub-category, or research and information need, $\overline{y^*_k}$ is the mean of the individual normalized ratings for the k-th category, sub-category, or research and information, and N is the number of categories, sub-categories, or research and information needs (within a category or sub-category) for each theme.

Raw (unbalanced) scores for each research and information need were calculated using:

$$(3) \qquad S_m = W_k R_m,$$

where S_m is the raw score for research or information need m and R_m is the weighted mean of all normalized ratings for research or information need m. Scores for research and information needs were used to rank priorities within each theme.

Depending on the structure of a hierarchy, the method used to calculate scores could influence the preferred choice. For example, in a hierarchy formed by criteria with alternatives under each of the criteria, if there is an unequal number of alternatives under each criteria, scores for alternatives could be inflated or deflated based on the amount of alternatives in the groupings using an unbalanced approach (Harker and Vargas 1987, Forman and Gass 2001, Ishizaka et al. 2011). This bias becomes particularly evident when the criteria and alternatives have similar ratings.

For example, consider a hierarchy with two criteria, each rated 5. Let the first criterion include two alternatives, let the second criterion include three alternatives, and let each of the alternatives be rated 4. The unbalanced scores (equation 3) for the criteria would be 5/10. The unbalanced scores for each alternative under the criterion 1 would be (5/10) (4/8) = 0.25. The unbalanced scores for each alternative under criterion 2 would be (5/10) (4/12) = 0.17. Thus, the alternatives under the criterion with the fewest alternatives would score highest even though all the alternatives had the same rating and the criteria had equal weights.

A balanced approach for the AHP weights the criteria to offset differences in numbers of alternatives. The adjustment factor is the product of the number of criteria and a ratio of the number of alternatives within a criterion and the total number of alternatives (equation 4). The outcome of balancing is that criteria with fewer research and information needs will be downweighted relative to criteria with more research and information needs. In the foregoing example, the weighting factor for alternatives under criterion 1 is (2) (2/5) = 0.8 and the weighting factor for alternatives under criterion 2 is

(2) (3/5) = 1.2. Applying these weighting factors to the unbalanced scores results in identical scores (0.2) for all five alternatives.

Because the criteria had similar ratings but differing numbers of sub-criteria and research and information needs, we used a balanced approach.

Category balanced scores were calculated using:

$$C_k = W_k (C)(n/N), \tag{4}$$

where C_k is the balanced score for category k, W_k is the weighted mean of all normalized ratings for category k, n is the number of research or information needs within a category, N is the total number of research and information needs in a theme, and C is the total number of categories within a theme.

Sub-category scores were calculated using a similar equation. Balanced scores for research and information needs were calculated using:

$$B_m = C_k R_m, \tag{5}$$

where B_m is the balanced score for research and information need m and R_m is the weighted mean of all normalized ratings for research or information need m.

Spearman rank-order correlation tests were used to test the null hypothesis of no association between the expert panel and stakeholders. The Spearman rank-order correlation coefficient (rho) was calculated using:

$$\rho_s = 1 - \frac{6\sum_{i=1}^{N} d_i^2}{N\left(N^2 - 1\right)}, \tag{6}$$

where ρ_s is the Spearman rank-order correlation coefficient, d_i is the difference in ranks (between groups), and N is the number of observations (research or information needs in each theme). Spearman's rho values were compared to critical values at 1% and 5% significance levels and levels at 5% were considered significant.

To address the non-random selection of expert panelists, sensitivity analyses were used to assess the robustness of the results. Responses from blocks of panelists and stakeholders were compared to test levels of association across blocks. We defined blocks as panel members or stakeholders affiliated with agencies, NGOs, academics, public, or the fishing industry. Blocks that include fewer than three participants per interest group were not included in comparisons.

Because substantial differences in rank ordering could occur even if Spearman tests indicated a strong correlation, we used pairwise plots to compare pairings of ranked research and information needs to help identify outliers. The Theil-Sen method, a non-parametric trend line estimator, was used to construct a trend line on paired rankings in the statistical program R. The Theil-Sen method (Gilbert 1987) combines the median pairwise slope with the median x and y values to estimate trend lines. Bootstrap resamples with replacement were generated 1000 times, with simulated Theil-Sen trend lines, to generate 95% confidence bands as illustrated in USEPA (2009). Points outside of the 95% confidence bands are considered outliers and are discussed in the results.

Results

Improving Ecosystem Health

For *Improving Ecosystem Health*, 115 stakeholder-suggested research and information needs were organized into a hierarchy of 5 categories and 16 sub-categories of closely related topics. Thirteen members of the expert panel and 94 stakeholders provided ratings on the *Improving Ecosystem Health* survey. The highest percentage (40%) of stakeholders identified themselves as academics. Agency personnel accounted for 26% of stakeholder responses, NGO members accounted for 20% of the responses, 9% of the respondents identified themselves as local people and were grouped as "public", and the remaining 4% identified themselves as being associated with commercial fishers. In contrast, the expert panel was composed of a higher percentage of agency personnel (54%), followed by NGO members (23%), academics (15%), and individuals associated with commercial fishing groups (8%). The majority, 68%, of the stakeholders listed their address as Alaska; 23% were from other states on the West Coast or Canada; the remaining 8% listed other U.S. states as their address. All of the expert panelists were Alaska residents.

Scores that reflect expert panel and stakeholder ratings are shown in the hierarchies included as Appendix (A3) and Appendix (A4). The top twenty research and information need priorities as ranked by the expert panel are reported in Table 1 and displayed in Figure 2. The top twenty research and information need priorities as ranked by the stakeholders are reported in Table 2 and displayed in Figure 3. Lettered codes in the tables and figures represent the category (first letter), sub-category (second letter) and

research and information need (third letter) shown in the *Improving Ecosystem Health* hierarchy (see appendices A3 and A4).

Spearman's rho for ranked research and information needs between the mean ratings by the expert panel and the mean ratings of the stakeholders ($\rho_s = 0.885$) was statistically significant at $\alpha = 0.001$. Therefore, there is sufficient evidence to reject the null hypothesis that there is no association between these groups. The correlation relationship between the expert panel and stakeholder ranking is shown in a pairwise plot with confidence bands (Figure 4). Within the top twenty priorities, two outliers were identified as being outside the confidence bands. Priority number 13 for the expert panel, "use seabird populations as indicators of ecosystem health", was ranked thirty-one by the stakeholders. Priority number 15 for the expert panel, "monitor the health and size of eelgrass beds", was ranked thirty-five by the stakeholders. It is important to note that although there were frequent differences in the rank order of research and information needs between the expert panel and the stakeholders, the differences in mean ratings rarely exceeded one standard deviation. (See Figure 2 and Figure 3.)

Fifteen of the top twenty research and information needs in the expert panel rankings were also in the top twenty research and information needs in the stakeholder rankings. The expert panel ranked research and information need priorities 1 through 14 more than one standard deviation above the mean rating of the 115 research and information needs; stakeholder ranked priorities 1 through 12 more than one standard deviation above the mean rating for all research and information needs (Figure 2 and Figure 3). The expert panel and stakeholders identified the same eleven research and

information needs more than one standard deviation above the mean rating. Stakeholders identified an additional research need, not in the expert panel, priority number 12, "Examine the relationship between deep ocean ecosystems of the Western Aleutian Islands and shallower Bering Sea", as also being more than one standard deviation above the mean. The expert panel identified three research and information needs, not in the stakeholder rankings, as being more than one standard deviation above the mean rating. These include priority number 12, "identify which species west of 160 have connections to North America and which are more closely connected to Asia," priority number 13, "use seabird populations as indicators of ecosystem health," and priority number 14, "monitor representative intertidal and nearshore subtidal ecosystems." The remaining research and information needs in the top twenty ranked priorities for both expert panelists and stakeholders were above the mean, but less than one standard deviation above the mean.

Thus not only was there strong correspondence between stakeholder and expert panel rankings of the 115 research and information needs in this theme, there was also concordance that the majority of the top research and information needs were notably more important than the remaining research and information needs in the *Improving Ecosystem Health* theme.

Pairwise comparisons of Spearman's rho between the ranking based on mean ratings by the expert panel and the mean ratings of individual interest groups (i.e., NGO, agency) within the expert panel were used to evaluate how sensitive the expert panel rankings were to variations in the makeup of the panel. The results are reported in

Table 3. All of the estimated correlations were statistically significant at $\alpha = 0.001$; therefore, there is sufficient evidence to reject the null hypothesis that there is no association between the overall panel mean rankings and the mean rankings based on subsets of the expert panel. A similar analysis was conducted comparing the mean rankings of all stakeholders with the mean rankings based on subsets (i.e., agency, NGO, academic, public, and fishing) within the stakeholders (Table 4). These correlations were also statistically significant at $\alpha = 0.001$. In addition, pairwise comparisons were used to measure the degree of association between the mean rankings based on subsets of the expert panel and corresponding subsets of the stakeholders (Table 5). These correlations were also statistically significant at $\alpha = 0.001$.

Results for *Improving Ecosystem Health* theme were also used to explore the extent to which balanced scores corresponded with unbalanced scores. Stakeholder and expert panel responses were more strongly correlated in the unbalanced scores (Appendix 10). In addition, the balanced scores exhibited more differences in rank ordering of research and information needs (Figure 4). On close examination, it is clear that the unbalanced approach inflated mean scores for research and information needs in sub-categories and categories with few research and information needs. For example, all five of the research and information needs in sub-category b "ecosystem linkages" of category D, "understand factors that influence and control ecosystem dynamics" were more than one standard deviation above the mean for the expert panel using the unbalanced approach (Appendix 9). Using the balanced approach, only one research need from this sub-category was in the top twenty priorities and this was above the mean but

below one standard deviation above the mean (Figure 2). Because stakeholders and expert panelists did not strongly favor particular categories or sub-categories, those categories with few research and information needs were rated higher when the unbalanced approach was used.

Enhancing Human Health and Safety

Stakeholder input on *Enhancing Human Health and Safety* yielded 23 research and information needs. These were organized into a hierarchy of three categories. Twelve members of the expert panel and 20 stakeholders, seven of whom were respondents to the initial scoping survey. Forty percent of the stakeholders identified themselves as agency personnel, 25% identified themselves as being affiliated with NGOs, 20% identified themselves as "public", and 15% identified themselves as academics. The mix of respondents on the expert panel differed; 58% identified themselves as agency personnel, 25% as NGO affiliates, 8% as academics, and 8% as associated with commercial fishing. Mean ratings of these research and information needs by the expert panel are shown in Appendix (A5); mean ratings from the stakeholders are shown in Appendix (A6). The top twenty research and information needs according to the mean of the expert panel ratings are reported in Table 6 and depicted in Figure 5; the stakeholders' top twenty research and information needs are reported in Table 7 and depicted in Figure 6. Lettered codes shown with each research and information need (Tables 6 and 7; Figures 5 and 6) represent the category (first letter) and research and information need (second letter) shown in the *Enhancing Human Health and Safety* hierarchy (see appendices A5 and A6).

Spearman's rho for rankings based on the mean of the expert panel ratings of all 23 research and information needs and the rankings based on the mean of the stakeholder ratings of those research and information needs ($\rho_s = 0.611$) was statistically significant at $\alpha = 0.05$. Therefore, there is sufficient evidence to reject the null hypothesis that there is no association between the rankings assigned by the expert panel and those assigned by the stakeholders. Both expert panel and stakeholders ranked research and information needs one through four more than one standard deviation above the mean of the 23 research and information needs in the *Enhancing Human Health and Safety* theme (Figure 5 and Figure 6). The expert panel and stakeholders identified two of the same highest priorities. The expert panel and the stakeholders identified the same 18 out of the top 20 research and information needs. Priority number 14 in the expert panel ranking, "locate former U.S. military dump sites and determine levels of toxic materials," and priority number 18, "determine if ballast water discharges impact the safety of commercial and subsistence seafoods," were not included in the top twenty priorities for the stakeholders. Priority number 17 in the stakeholder ranking, "determine the human health risks related to boats coming to port (i.e., disease)," and priority number 18, "need to know the nutritional value of fish and shellfish and if it changes over time" were not included in the top twenty ranked priorities for the expert panel.

Although correlation tests between the expert panel and stakeholders showed strong and statistically positive correlations between the groups, a pairwise plot shows some substantial differences in the rankings (Figure 7). The pairwise plot showed ten priorities to be outliers. Four priorities ranked lower by the stakeholder than the expert

panel were in category A, "reduce risk to people from contaminants" and two priorities ranked higher by the stakeholders were in category B, "reduce risk to people from disease".

Spearman's correlations were also used to compare the mean ranked priorities of the entire expert panel with those of subsets (i.e., NGO, agency) of the expert panel (Table 8). The estimated correlations were statistically significant at $\alpha = 0.001$; therefore, there is sufficient evidence to reject the null hypothesis that the rankings are significantly different between the mean of the expert panel as a whole and the mean ratings of subsets of the expert panel. In a similar analysis of the stakeholders (Table 8), the majority of the estimated correlations were significant for all stakeholders with those of subsets of stakeholders (i.e., agency, NGO, academic). However, the correlation between rankings based on the mean ratings submitted by "public" was not statistically significant at $\alpha = 0.05$ for the whole group of stakeholders or any other subgroup. Similarly, the correlation between the stakeholder agency and the academic subgroup was not statistically significant at $\alpha = 0.05$ (Table 9). Thus, there is insufficient evidence to reject the null hypothesis that the rankings based on these groups differ.

Pairwise comparisons were conducted between rankings based on mean ratings of subsets of the expert panel and subsets of the stakeholders (Table 10). Estimated correlations for the agency subgroup of the expert panel, compared to the agency and NGO subgroup for the stakeholders, were both statistically significant $\alpha = 0.01$ or $\alpha = 0.001$. However the estimated correlation between rankings based on the mean ratings submitted by the NGO subgroup for the expert panel and any other subgroups was

not significant at $\alpha = 0.05$. Therefore, there is insufficient evidence to reject the null hypothesis that the rankings based on these groups differ.

Marine Transportation and Security

Twenty stakeholder-suggested research and information needs were organized into a hierarchy of four categories. Ratings were completed by 13 members of the expert panel and eight stakeholders. Most (38%) of the stakeholders were aligned with industry; 25% were affiliated with NGOs; 25% were agency personnel; and 13% identified themselves as "public". The low number of stakeholder responses precluded comparisons between interest groups. The highest percentage of members of the expert panel were agency personnel (31%); NGO affiliates, academics, and industry members each represented 23% of the expert panel responses. Mean ratings of the research and information needs by the expert panel are included as Appendix (A7); mean stakeholder ratings are shown in Appendix (A8). The ranked research and information needs based on the mean ratings by the expert panel are reported in Table 11 and Figure 8; mean stakeholder ratings are reported in Table 12 and Figure 9. Lettered codes shown with each research and information need represent the category (first letter), and research and information need (second letter) that correspond to the *Marine Transportation and Security* hierarchy (see appendices A5 and A6).

Spearman's rho for rankings based on the mean ratings of all 20 research and information needs by the expert panel and those based on the mean ratings of the stakeholders ($\rho_s = 0.714$) was statistically significant at $\alpha = 0.001$. Therefore, there is sufficient grounds to reject the null hypothesis that there is no association between these

groups. Both expert panel and stakeholders rated their top three research and information needs more than one standard deviation above the mean for this theme (Figure 8 and Figure 9). One of the highest priorities identified by both the expert panel and stakeholders was the priority, "develop a regional oil spill response plan". Both groups identified four research and information needs ranked more than one standard deviation below the mean, indicating a substantially lower preference for these research and information needs. Since there were twenty total research and information needs within this theme, both expert panel and surveyed stakeholders contained the same twenty priorities.

A pairwise plot of the means of the expert panel and stakeholder ranked priorities shows seven priorities outside of confidence bands (Figure 10). These include priority 3 for the expert panel, "assess the risks and impacts of ballast water and small fuel discharges on the environment," ranked thirteen by the stakeholders. Priority 4 for the expert panel, "determine if current infrastructure (tugs, booms, refueling, marine services, etc.) is sufficient to respond to shipping accidents and oil spills", ranked first for the stakeholders. Priority 8 for the expert panel, "determine if island passes are bottlenecks that warrant additional shipping regulation (e.g., designated shipping lanes, tug boat escorts)", ranked fourth by the stakeholders. Priority 10 for the expert panel, "develop shipping traffic maps for anticipated changes in shipping and fishing activity", ranked fourteen for the stakeholders. Priority 11 for the expert panel, "provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels", ranked sixth for the stakeholders. Priority 12 for the expert panel,

"assess marine shipping impacts with attention to anticipated effects of changes in lanes and routes", ranked eighteen for the stakeholders. Priority 17 for the expert panel, "is an inter-island marine transportation system feasible for transportation of goods and people?" ranked eighth for the stakeholders.

Rankings based on the mean ratings of the full expert panel were compared with rankings based on the mean ratings of subsets of the expert panel (Table 13). All of these estimated correlation coefficients were statistically significant at $\alpha = 0.01$ or $\alpha = 0.001$, allowing rejection of the null hypothesis that the rankings are dissimilar. Correlation coefficients for subsets of the expert panel compared to other subsets of the expert panel were significant for expert panel NGO and other subgroups at $\alpha = 0.05$ or $\alpha = 0.01$. However, the estimated correlations for rankings based on the mean of fishing industry affiliated expert panelists and any other subgroup in the expert panel was not significant at $\alpha = 0.05$. Thus, there is insufficient evidence to reject the null hypothesis that the rankings based on these groups differ. Because there were three or fewer respondents within each subset of the stakeholders, we did not conduct pairwise comparisons between the rankings based on mean ratings of subsets of the stakeholders.

Discussion

In environmental decision-making and management, finding an appropriate method to incorporate stakeholder input is a necessary component for success. However, because the input is voluntary, there is concern that it may narrowly reflect the views of non-representative stakeholders. This concern is particularly apropos when stakeholders

express widely divergent views. When agencies instead turn to expert panels, the concern is that the panels may not be reflective of stakeholder interests and that the perspective of the panel may be an artifact of the panelist selection process. It is desirable to have a process that is robust to the composition of the panel or self-selection of stakeholders who submit input.

Previous applications of the AHP in marine resource management indicate that disagreements in priorities often occur when diverse stakeholder groups are presented with choices that align with their own interest groups. For example, an evaluation of preferences for Australian fisheries management objectives found stakeholder groups associated with industry were most concerned with maximizing profit and conservation groups with minimizing environmental damage (Pascoe et al. 2009). Similarly, Mardle et al. (2004) found different priorities between stakeholder groups for fishery management in the English Channel; environmental groups prioritized issues such as environmental protection while individuals from the catching sector prioritized issues such as employment. Innes and Pascoe (2010) evaluated the importance of environmental impacts of fishing to stakeholder groups across Europe and found that almost all surveyed groups preferred reducing habitat damage, with the exception of the commercial fishing sector, which preferred priorities to reduce commercial fishing discards.

We expected to see differences in prioritized research needs when comparing recommendations from an expert panel to those of a broader set of stakeholders. The expert panel members were selected based on their recognized expertise in the topic areas for the ocean research themes and were representative of their affiliated organizations.

The stakeholders were self-selected participants, representing their own opinions, with varying levels of knowledge and differing affiliations. Nevertheless, Spearman rank correlation tests consistently indicated that there is strong concordance in ranking of research and information needs between the stakeholders and the expert panel. Spearman tests also indicated concordance in the ranking of research and information needs between subsets of the expert panel and subsets of the stakeholders for *Improving Ecosystem Health*. More differences in the ranking of research and information needs were found between subsets of the expert panel and subsets of stakeholders for *Enhancing Human Health and Safety*, and *Marine Transportation and Security*.

Expert panel and stakeholder comparison

Spearman's correlation tests showed strong associations between the expert panel and the stakeholders for all three ocean research themes examined in this study. The majority of the top twenty research and information needs for *Enhancing Human Health and Safety*, and *Improving Ecosystem Health* were similar between the expert panel and stakeholders. For stakeholders and panelists, the highest priority research and information needs for *Improving Ecosystem Health,* relate to increasing a basic knowledge of the region. These highest priorities include almost all research and information needs of category A, "catalog organisms and identify habitats" (Figure 2, Figure 3, A3, A4). This indicates that panelists and stakeholders agree that a lack of basic information on the occurrence and abundance of species and habitats hinders management of the Aleutian Islands ecosystem. Two of the highest priority research and information needs were also in sub-category b "identify indicators" of category B, "identify indicators, monitor trends

and predict changes" (Figure 2, Figure 3, A3, A4). This indicates consensus on the need for a better monitoring for changes in the Aleutian Islands ecosystem.

Two of the highest priorities that the expert panel and stakeholders agreed on indicate that panelists and stakeholders concur on a need for more planning relating to increasing community health and safety in the Aleutian Islands. For *Marine Transportation and Security* both expert panel and stakeholders identified priority "develop a regional oil spill response plan", as a highest priority (Figure 9 and Figure 10). This suggests that both the expert panel and stakeholders support the development and future implementation of the recent Aleutian Islands risk assessment report, that addresses responses to oil spills for the region (AIRAMT 2011).

For *Improving Ecosystem Health*, pairwise plots showed close agreement in lower and higher ranked priorities with the most variation occurring for mid-ranked priorities (Figure 4). This suggests that both groups generally agreed on the highest and lowest priorities but disagreed on the rank of intermediate-value research and information needs. For example, research priority, "involve residents in science that goes beyond data collection", was above the mean ratings for stakeholders (ranked at 26) but below the mean ratings for the expert panel (ranked at 65). Areas of disagreement could point out differences in values or knowledge between stakeholders and expert panelists. For example, stakeholders could be unaware of studies where involving residents in science proved unsuccessful, indicating a communication lapse between stakeholders experts. On the other hand, expert panelists could be unaware of a desire of residents to become more involved in science. These areas of disagreement could be explored in future studies

where the highest and lowest priorities are removed and the middle ranked priorities are reassessed through new surveys. For example, if expert panelists were made aware of the desire of stakeholders to be more involved in science, new ratings of survey questions could be used to explore how this information influences research priorities.

The strong agreement found between the expert panel and stakeholders, as indicated by Spearman tests, may have been influenced by the lack of conflicting objectives related to the survey topics. The survey questions did not likely highlight topics that would put different stakeholder groups that use the Aleutian Islands in conflict. For example, none of the survey questions asked participants to rate a need for expanded fishing opportunities in the Aleutian Islands that individuals associated with the fishing industry could rate substantially higher than other stakeholder groups such as those with conservation interests as demonstrated in Mardle et al. (2004). In addition, there was not an obvious conflict in the agendas of participating stakeholder groups wanting to utilize the marine environment in a substantially different manner than other stakeholder groups. For example, there were no questions related to expanding oil and gas opportunities in the region that individuals associated with oil and gas industries might rate substantially higher than other stakeholder groups such as those with conservation interests.

Previous research also suggests that stakeholder attitudes, such as the desire for job creation, can influence preferences toward some priorities over others (Whitmarsh and Palmieri 2009; Heck et al. 2011). Surveys for stakeholder attitudes toward salmon farming objectives in Scotland indicated regional differences with more approval of

aquaculture expansion in regions with high unemployment rates (Whitmarsh and Palmieri 2009). Overall, the survey questions related to improving knowledge of the marine ecosystem of the Aleutian Islands and the task presented to stakeholders and panelists was to prioritize those needs. This may have substantially reduced the possibility of disagreements based on self-interest.

Individual interest group comparison

Strong correlations were also found between rankings based on the mean ratings of individuals aligned with various interest groups within the expert panel and among stakeholders for *Improving Ecosystem Health*. This also indicates robustness for results in the sense that priorities did not change when the rankings were based on varied subsets of stakeholders.

These similarities could be due to similarities in backgrounds, such as education, of those affiliated with stakeholder groups. Surveyed participants self-identified affiliations with interest groups; however, some overlap may occur between interest groups. For example, a former student affiliated with an academic interest group may later be employed by an agency or NGO. Therefore, it is not surprising that we would find similarities in preferences between these interest groups. In addition, those affiliated with the fishing stakeholder group may have similar educational backgrounds to those in other interest groups that may be unique to Alaska. For example, representatives of the fishing industry who are active in Alaska Region fisheries management often have graduate degrees in fisheries or marine biology. Stronger disagreements are likely to occur in regions where stakeholders are more diverse.

In addition, other characteristics of stakeholders may influence the way they rate questions. For example, differences were found in stakeholder preferences toward performance indicators for marine protected area management in the Mediterranean, but similarities were found among individuals with similar interests besides just their interest group affiliation (Himes 2007). This suggests that differences in interests could be related to other factors besides the affiliation of the individual. Similarly, Heck et al. (2011) evaluated expectations for marine protected area performance on the Southwest coast of British Columbia and found clear differences between user and non-user groups. Future studies could collect more information from stakeholders to explore preferences of stakeholders that utilize marine resources of the Aleutian Islands to those that have never been to the Aleutian Islands or not Alaska residents. In addition an approach similar to that used in Lew et al. (2010), could be used to devise a formally structured sampling effort of random households in the U.S. to be compared to volunteered responses such as those we obtained through the web-based survey.

Spearman tests of similarities between subsets of the expert panel and tests of similarities among subsets of the stakeholders suggested less consistency for *Enhancing Human Health and Safety* and *Marine Transportation and Security* (Tables 8, 9 10, and 13). Because these themes had a reduced scope of research and information needs and elicited fewer responses, increased response variability is not surprising. Spearman tests consistently showed non-significant correlation coefficients for comparisons that included low levels of participants. For example, none of the estimated correlations

between expert panelists affiliated with the fishing industry and other subsets within the expert panel were significant for the theme *Marine Transportation and Security*.

Although diverse interest groups participated in the surveys, some of the interest groups, such as the fishing group and the public, had low participation numbers. Finding appropriate electronic mailing lists or persons with expertise in *Marine Human Health and Safety*, and *Marine Transportation and Security* was more difficult than finding those for *Improving Ecosystem Health*. This may be an important reason why fewer responses were received for these themes. In addition, a large percentage of the original respondents did not state their affiliation; therefore, it is possible that the responses received from stakeholders such as those from fishing groups were proportional to participation from the original stakeholders. In that case, we would expect low participation from these groups because their interests may not be represented in the survey questions and they may not have considered their input to be influential.

We also found that the structuring of the hierarchy and the AHP approach used for scoring priorities plays an important role in ranking priorities. Although Spearman tests for stakeholders and the expert panel were significant using the unbalanced and balanced approach, our results showed a higher priority for research priorities in categories and sub-categories with fewer research and information needs using the unbalanced approach. This contributed to our decision to use the balanced approach.

Under certain circumstances, using the unbalanced approach may be appropriate. For example, if there are strong differences in the ratings assigned to different criteria (i.e., categories/sub-categories). In that case, strong high or low preferences for criteria

will be reflected in the final scores assigned to the alternative. In other scenarios, where the hierarchy levels contain different levels of complexity, an unbalanced approach may also be appropriate. For example, if fewer alternatives are grouped under a criterion, but the alternatives carry with them more complexity, then it may be appropriate for these alternatives to receive a higher weight to adjust for the higher level of information encompassed in these alternatives.

The AHP could be useful in the RFMC process where action alternatives are evaluated using the ten National Standards. Currently the council and NOAA staff are tasked with evaluating action alternatives for consistency with the ten National Standards in the preparation of Environmental Assessments (EA), Regulatory Impact Reviews (RIR) and Initial Regulatory Flexibility Analyses (IRFA). However, the MSA does not provide guidance on how to weight National Standards in relationship to one another. The AHP could assist in assigning explicit scores to the National Standards through methods similar to those used in this study or through pairwise comparisons. Pairwise comparisons of alternatives relative to criteria is manageable when the number of alternatives is small, but when the number of alternatives and criteria is large it is impractical to conduct pairwise comparisons.

For example, we could structure a hierarchy where optimum yield is the overarching goal and the criteria represent the ten National Standards. The performance of each proposed action alternative and the no-action alternative could be scored relative to each of the National Standards (See, e.g., Figure 11). The alternative that scores

highest for the weighted National Standards would be considered the preferred alternative.

This type of approach could be useful for the Advisory Panel or the SSC in providing recommendations to the Council. In addition, the Council staff could solicit this type of information from stakeholders, through written or web-based surveys, to compare preferred alternative between stakeholders and the Council. This would provide insights into differences between the Council bodies and stakeholders. To examine robustness of the alternatives, the weights of the National Standards could be systematically varied; alternatives that emerge as the preferred alternative over a wide range of weights cold be considered more reliable than alternatives that are very sensitive to particular weights.

For example, if National Standard one—preventing overfishing while achieving optimum yield—was rated highly compared to National Standard two—basing decisions upon the best scientific information available—then action alternatives that best address National Standard one will consistently emerge as the preferred alternative.

Although providing weights for the National Standards may generate more scrutiny from some stakeholder groups, the decision-making process would become more transparent to the public. Previous applications of the AHP in fisheries management demonstrate its usefulness and this study suggests that the AHP can be used to aggregate stakeholder input in fisheries management.

Conclusion

The application of the AHP in our study provides a transparent process for incorporating input from multiple stakeholder groups. Our study shows the preferences of an expert panel can be very similar to those of a broader set of stakeholders and demonstrate the ability to reach agreement among a diverse set of stakeholders. Results did not appear to be sensitive to the types of interest groups involved for *Improving Ecosystem Health*, but were more sensitive for *Enhancing Human Health and Safety* and *Marine Transportation and Security*. Results show common preferences, highlight differences, and provide a solution that can satisfy multiple stakeholder groups. Furthermore, our results suggest that group decision-making techniques, such as the AHP, are appropriate for incorporating stakeholder preferences into environmental planning and decision-making. The AHP may be helpful as ecosystem-based management approaches progress in a future CMSP process where multiple user groups need to coordinate for planning efforts.

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Table 1. Expert panel ranked top twenty research and information needs for *Improving Ecosystem Health*. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

Rank	Research/information need	Code
1	Monitor species distribution and abundance indices.	Aaa
2	Identify and map the foraging, spawning and nursery habitats of marine species.	Aba
3	Study the temporal and spatial distribution and abundance of pollock in Steller sea lion Critical Habitat.	Aad
4	Monitor indicators of ecosystem change.	Bbb
5	Develop high resolution maps of seafloor geology, morphology and habitat.	Abb
6	Improve identification and classification of invertebrates caught in trawl surveys.	Aac
7	Identify and catalogue species in decline and monitor their population shifts.	Bbc
8	Determine the winter distribution of seabirds in the Aleutian Islands.	Aae
9	Identify Essential Fish Habitat (feeding and spawning habitat) for Atka mackerel.	Abe
10	Identify Pacific Ocean Perch spawning sites.	Abd
11	Identify and map the distribution of kelp and other macroalgae.	Abc
12	Identify which species west of 160 have connections to North America and which are more closely connected to Asia.	Aab
13	Use seabird populations as indicators of ecosystem health.	Bbe
14	Monitor representative intertidal and nearshore subtidal ecosystems.	Bbd
15	Monitor the health and size of eelgrass beds.	Bbf
16	Examine the role of marine habitat in fisheries production and ecosystem health.	Ccc
17	Study the role of deep passes in limiting the distribution of species.	Dbb
18	Examine the functional roles of commercial species in marine food webs.	Dag
19	Investigate linkages between marine habitats and resource productivity.	Ccb
20	Determine the trophic effects of depleting a target species.	Dad

Table 2. Stakeholder's ranked top twenty research and information needs for *Improving Ecosystem Health*. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

Rank	Research/information need	Code
1	Monitor species distribution and abundance indices.	Aaa
2	Identify and map the foraging, spawning and nursery habitats of marine species.	Aba
3	Study the temporal and spatial distribution and abundance of pollock in Steller Sea Lion Critical Habitat.	Aad
4	Determine the winter distribution of seabirds in the Aleutian Islands.	Aae
5	Improve identification and classification of invertebrates caught in trawl surveys.	Aac
6	Identify Essential Fish Habitat (feeding and spawning habitat) for Atka mackerel.	Abe
7	Identify and map the distribution of kelp and other macroalgae.	Abc
8	Develop high resolution maps of seafloor geology, morphology and habitat.	Abb
9	Identify Pacific Ocean Perch spawning sites.	Abd
10	Identify and catalogue species in decline and monitor their population shifts.	Bbc
11	Monitor indicators of ecosystem change.	Bbb
12	Examine the relationship between deep ocean ecosystems of the Western Aleutian Islands and shallower Bering Sea.	Dba
13	Examine the functional roles of commercial species in marine food webs.	Dag
14	Determine the trophic effects of depleting a target species.	Dad
15	Examine the role of marine habitat in fisheries production and ecosystem health.	Ccc
16	Examine the links between fish and invertebrate populations in the Aleutian Islands to the open ocean ecosystem and to the Bering Sea and Gulf of Alaska.	Dbe
17	Study the linkages between the nearshore habitat and pelagic ecosystems.	Dbd
18	Determine if predator/prey relationships hinder the recovery of depleted species.	Dae
19	Investigate linkages between marine habitats and resource productivity.	Ccb
20	Determine the importance of forage fish, including capelin, to upper trophic production in the Aleutians.	Daf

Table 3. Spearman's rank-order correlation coefficients and number of individuals comparing ranked priorities between all expert panelists (full panel) and individual interest groups (i.e., NGO, agency) for *Improving Ecosystem Health*. Estimated correlations are shown below the main diagonal; values above the main diagonal represent number of individuals used for the comparisons.

	Full panel	NGO	Agency
Full panel	---	13	13
NGO	0.880***	---	10
Agency	0.927***	0.731***	---

$P<0.05$*; $P < 0.01$**; $P < 0.001$***

Table 4. Spearman's rank-order correlation coefficients and number of individuals comparing ranked priorities between all stakeholder's (Full SH) and individual interest groups (i.e., agency, NGO, academic, public, and fishing) for *Improving Ecosystem Health*. Estimated correlations are shown below the main diagonal; values above the main diagonal represent number of observations used for the comparisons.

	Full SH	Agency	NGO	Academic	Public	Fishing
Full SH	---	94	94	94	94	94
Agency	0.922***	---	43	62	33	28
NGO	0.931***	0.824***	---	57	28	23
Academic	0.972***	0.852***	0.893***	---	47	42
Public	0.771***	0.665***	0.703***	0.710***	---	13
Fishing	0.776***	0.675***	0.707***	0.732***	0.620***	---

$P<0.05$*; $P < 0.01$**; $P < 0.001$***

Table 5. Spearman's rank-order correlation coefficients and number of individuals comparing ranked priorities between individual interest groups for the expert panelists (i.e., panel agency and panel NGO) and individual interest groups for the stakeholders (i.e., SH agency and SH NGO) for *Improving Ecosystem Health*. Estimated correlations are shown below the main diagonal; values above the main diagonal represent number of observations used for the comparisons.

	Panel agency	SH agency	Panel NGO	SH NGO
Panel agency	---	31	10	26
SH agency	0.768***	---	27	43
Panel NGO	0.731***	0.747***	---	22
SH NGO	0.774***	0.824***	0.755***	---

$P<0.05$*; $P < 0.01$**; $P < 0.001$***

Table 6. Expert panel ranked top twenty priorities for *Enhancing Human Health and Safety*. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

Rank	Research/information need	Code
1	Design search and rescue programs to effectively respond to emergencies throughout Aleutian Area.	Ch
2	Develop personal, community, and regional emergency response preparedness plans.	Cf
3	Determine contaminant loads in commercial and subsistence resources harvested in the region.	Ac
4	Determine the sources and pathways of the major pollutants in the Aleutian Islands.	Ad
5	Promote human health and safety in the Aleutian Island region through education and outreach.	Cb
6	Can the timing of fisheries be optimized to minimize human casualties associated with fishing.	Ci
7	Determine the most serious immediate human health and safety needs in region.	Ca
8	Develop effective warning systems to alert community members to algal blooms, contaminant spills, and other health hazards.	Aa
9	Distribute information on safe consumption levels of contaminants for local and imported seafood	Ab
10	Determine what zoonotic diseases are active in foods such as shellfish, fish and marine mammals.	Bd
11	Determine risks and impacts to human health of harmful algal blooms in the Aleutian Islands. What are the safest times of year to harvest bivalves.	Ae
12	Improve monitoring to warn the public or to certify specific shellfish harvest areas as safe.	Ah
13	Estimate the human health risks of increased shipping traffic.	Cj
14	Locate former U.S. military dump sites and determine levels of toxic materials.	Af
15	Need to know how coastal zone development affects health.	Ce
16	Develop protocols to increase operation safety for government, commerce and military.	Cg
17	Implement a human disease surveillance program in the Aleutian Island region.	Ba
18	Determine if ballast water discharges impact the safety of commercial and subsistence seafoods.	Ai
19	Investigate conditions (natural or anthropogenic) that trigger harmful algal blooms.	Ag
20	Determine if changing local diets affect disease incidence.	Bc

Table 7. Stakeholder's ranked top twenty priorities for *Enhancing Human Health and Safety*. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

Rank	Research/information need	Code
1	Determine the most serious immediate human health and safety needs in region.	Ca
2	Promote human health and safety in the Aleutian Islands region through education and outreach.	Cb
3	Develop personal, community, and regional emergency response preparedness plans.	Cf
4	Design search and rescue programs to effectively respond to emergencies throughout Aleutian Area.	Ch
5	Determine what zoonotic diseases are active in foods such as shellfish, fish and marine mammals.	Bd
6	Implement a human disease surveillance program in the Aleutian Island region.	Ba
7	Distribute information on safe consumption levels of contaminants for local and imported seafood	Ab
8	Improve monitoring to warn the public or to certify specific shellfish harvest areas as safe.	Ah
9	Develop protocols to increase operation safety for government, commerce and military.	Cg
10	Determine contaminant loads in commercial and subsistence resources harvested in the region.	Ac
11	Estimate the human health risks of increased shipping traffic.	Cj
12	Determine risks and impacts to human health of harmful algal blooms in the Aleutian Islands. What are the safest times of year to harvest bivalves.	Ae
13	Determine the sources and pathways of the major pollutants in the Aleutian Islands.	Ad
14	Need to know how coastal zone development affects health.	Ce
15	Determine if changing local diets affect disease incidence.	Bc
16	Develop effective warning systems to alert community members to algal blooms, contaminant spills, and other health hazards.	Aa
17	Determine the human health risks related to boats coming to port (i.e., disease).	Bb
18	Need to know the nutritional value of fish and shellfish and if it changes over time.	Cd
19	Investigate conditions (natural or anthropogenic) that trigger harmful algal blooms.	Ag
20	Can the timing of fisheries be optimized to minimize human casualties associated with fishing.	Ci

Table 8. Spearman's rank-order correlation coefficients and number of individuals comparing ranked priorities between all expert panelists (full panel) and individual interest groups (i.e., NGO, Agency) for *Enhancing Human Health and Safety*. Estimated correlations are shown below the main diagonal; values above the main diagonal represent number of observations used for the comparisons.

	Full panel	Agency	NGO
Full panel	---	12	12
Agency	0.912***	---	10
NGO	0.635***	0.354	---

$P<0.05$*; $P < 0.01$**; $P < 0.001$***

Table 9. Spearman's rank-order correlation coefficients and number of individuals comparing ranked priorities between all stakeholders (full SH) and individual interest groups (i.e., agency, NGO, academic, public) for *Enhancing Human Health and Safety*. Estimated correlations are shown below the main diagonal; values above the main diagonal represent number of observations used for the comparisons.

	Full SH	Agency	NGO	Academic	Public
Full SH	---	20	20	20	20
Agency	0.787***	---	13	11	12
NGO	0.759***	0.475*	---	8	9
Academic	0.656***	0.396	0.434*	---	7
Public	0.364	0.051	0.308	0.172	---

$P<0.05$*; $P < 0.01$**; $P < 0.001$***

Table 10. Spearman's rank-order correlation coefficients and number of individuals comparing ranked priorities between individual interest groups for expert panelists (i.e., panel agency and panel NGO) and individual interest groups for stakeholders (i.e., SH agency and SH NGO) for *Enhancing Human Health and Safety*. Estimated correlations are shown below the main diagonal; values above the main diagonal represent number of observations used for the comparisons.

	Panel agency	SH agency	Panel NGO	SH NGO
Panel agency	---	15	10	12
SH agency	0.510**	---	11	13
Panel NGO	0.354	0.020	---	8
SH NGO	0.535***	0.475*	0.031	---

$P<0.05$*; $P < 0.01$**; $P < 0.001$***

Table 11. Expert panel research and information needs for *Marine Transportation and Security*. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

Rank	Research and information need	Code
1	Develop a regional oil spill response plan.	Ad
2	Identify transportation routes that cross sensitive habitats.	Cd
3	Assess the risks and impacts of ballast water and small fuel discharges on the environment.	Cg
4	Determine if current infrastructure (tugs, booms, refueling, marine services, etc.) is sufficient to respond to shipping accidents and oil spills.	Ac
5	Determine how traffic related to anticipated Outer Continental Shelf (OCS) exploration and development will impact the Aleutian Islands.	Cc
6	Examine methods to control shipping (e.g., require VMS or emergency transponders and sailing plans on all transiting vessels).	Ba
7	Examine alternatives for managing environmental impacts of shipping (e.g., traffic lanes, no transit zones around critical habitat, speed limits).	Cf
8	Determine if island passes are bottlenecks that warrant additional shipping regulation (e.g., designated shipping lanes, tug boat escorts).	Bb
9	Determine disturbance impacts to marine life and habitat in areas of occasional vs. steady marine traffic.	Ce
10	Develop shipping traffic maps for anticipated changes in shipping and fishing activity.	Ab
11	Provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels.	Be
12	Assess marine shipping impacts with attention to anticipated effects of changes in lanes and routes.	Cb
13	Improve reporting and forecasting of sea conditions.	Bd
14	Regularly update bathymetric maps of the seafloor and currents models through the Aleutian Islands passes to increase transportation safety.	Bc
15	Map habitats and the effects of shipping, fishing and marine debris on those habitats.	Ch
16	Estimate the frequency and causes of collisions with whales with increased shipping.	Ca
17	Is an inter-island marine transportation system feasible for transportation of goods and people?	Db
18	Determine if changes in mandatory landing locations for fisheries in the region will reduce transportation costs.	Da
19	Determine the socioeconomic impacts of increased transit shipping.	Dc
20	Determine incentives to attract private investment in infrastructure needed for emergency response.	Aa

Table 12. Stakeholder's research and information needs for *Marine Transportation and Security*. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

Rank	Research/information need	Code
1	Determine if current infrastructure (tugs, booms, refueling, marine services, etc.) is sufficient to respond to shipping accidents and oil spills.	Ac
2	Develop a regional oil spill response plan.	Ad
3	Determine how traffic related to anticipated Outer Continental Shelf (OCS) exploration and development will impact the Aleutian Islands.	Cc
4	Determine if island passes are bottlenecks that warrant additional shipping regulation (e.g., designated shipping lanes, tug boat escorts).	Bb
5	Identify transportation routes that cross sensitive habitats.	Cd
6	Provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels.	Be
7	Examine methods to control shipping (e.g., require VMS or emergency transponders and sailing plans on all transiting vessels).	Ba
8	Is an inter-island marine transportation system feasible for transportation of goods and people?	Db
9	Examine alternatives for managing environmental impacts of shipping (e.g., traffic lanes, no transit zones around critical habitat, speed limits).	Cf
10	Regularly update bathymetric maps of the seafloor and currents models through the Aleutian Islands passes to increase transportation safety.	Bc
11	Map habitats and the effects of shipping, fishing and marine debris on those habitats.	Ch
12	Determine disturbance impacts to marine life and habitat in areas of occasional vs. steady marine traffic.	Ce
13	Assess the risks and impacts of ballast water and small fuel discharges on the environment.	Cg
14	Develop shipping traffic maps for anticipated changes in shipping and fishing activity.	Ab
15	Determine if changes in mandatory landing locations for fisheries in the region will reduce transportation costs.	Da
16	Improve reporting and forecasting of sea conditions.	Bd
17	Determine incentives to attract private investment in infrastructure needed for emergency response.	Aa
18	Assess marine shipping impacts with attention to anticipated effects of changes in lanes and routes.	Cb
19	Estimate the frequency and causes of collisions with whales with increased shipping.	Ca
20	Determine the socioeconomic impacts of increased transit shipping.	Dc

Table 13. Spearman's rank-order correlation coefficients and number of individuals comparing ranked priorities between all expert panelists (full panel) and individual interest groups (i.e., NGO, agency, fishing, academic) for *Marine Transportation and Security*. Estimated correlations are shown below the main diagonal; values above the main diagonal represent number of observations used for the comparisons.

Interest group	Full panel	Agency	NGO	Fishing	Academic
Full Panel	---	13	13	13	13
Agency	0.841***	---	7	7	7
NGO	0.632**	0.444*	---	6	6
Fishing	0.591**	0.283	0.202	---	6
Academic	0.756***	0.570**	0.456*	0.198	---

$P<0.05$*; $P < 0.01$**; $P < 0.001$***

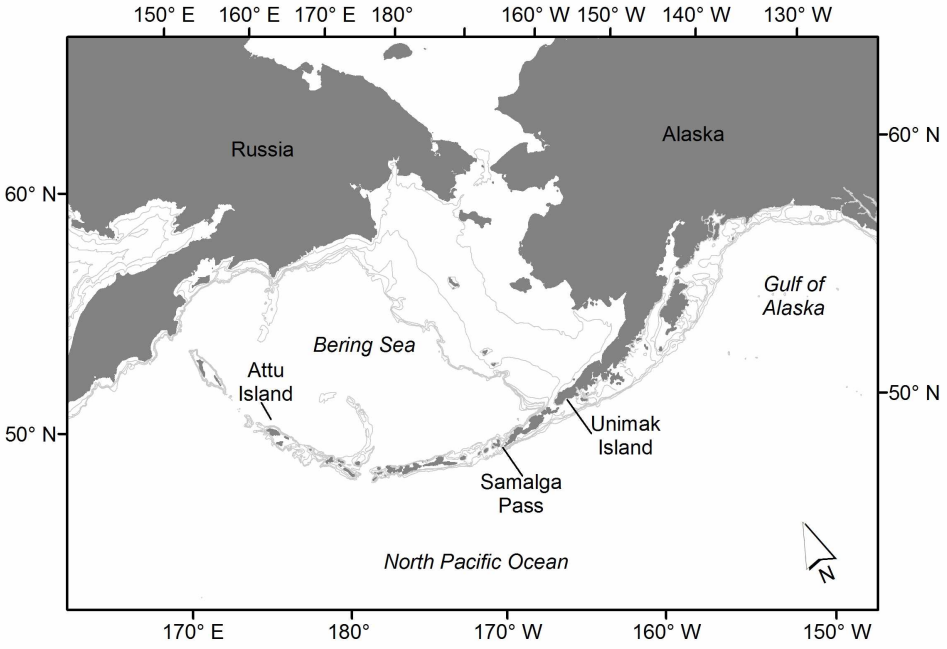

Figure 1. The Aleutian Islands regional marine research plan boundary extends from Unimak Island to Attu Island. Contour lines represent 50 meter isobaths up to a maximum 400 meters. Source: ArcGIS Version 9.3.1

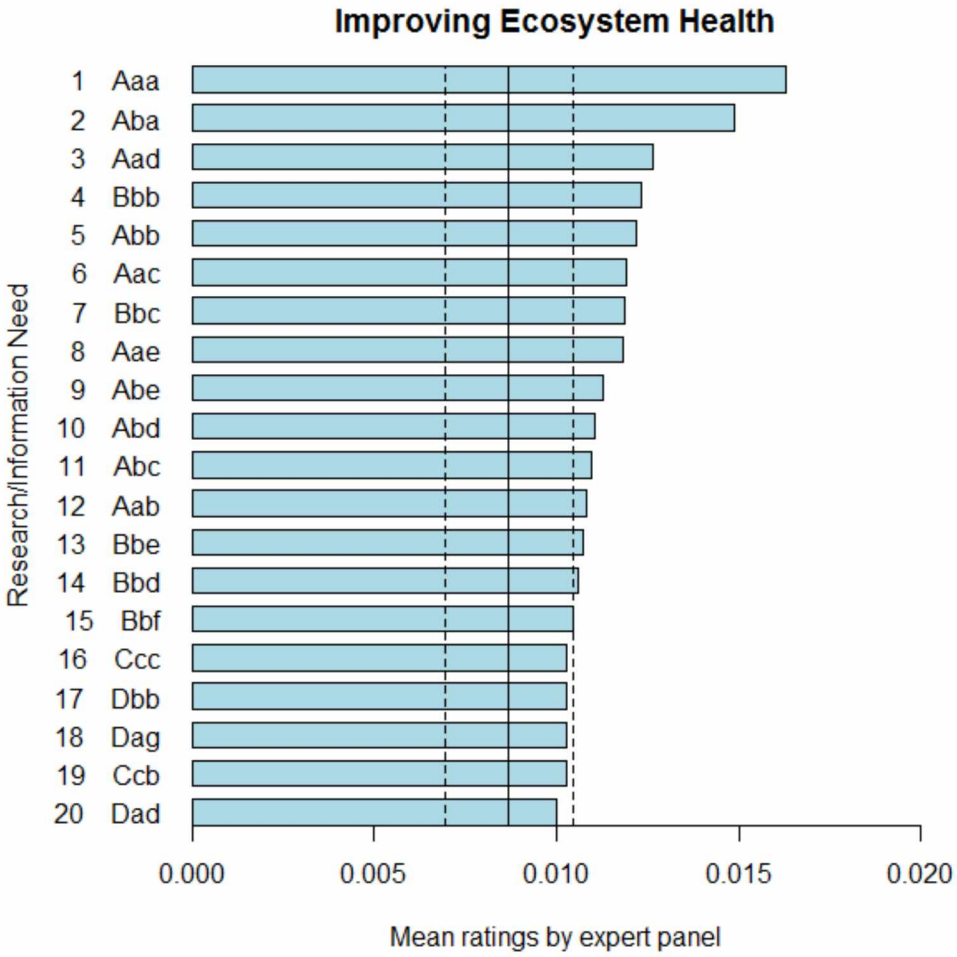

Figure 2. Top twenty research and information needs for Improving Ecosystem Health based on mean ratings by the expert panel. The solid line represents the overall mean; dashed lines represent plus and minus one standard deviation from the mean. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

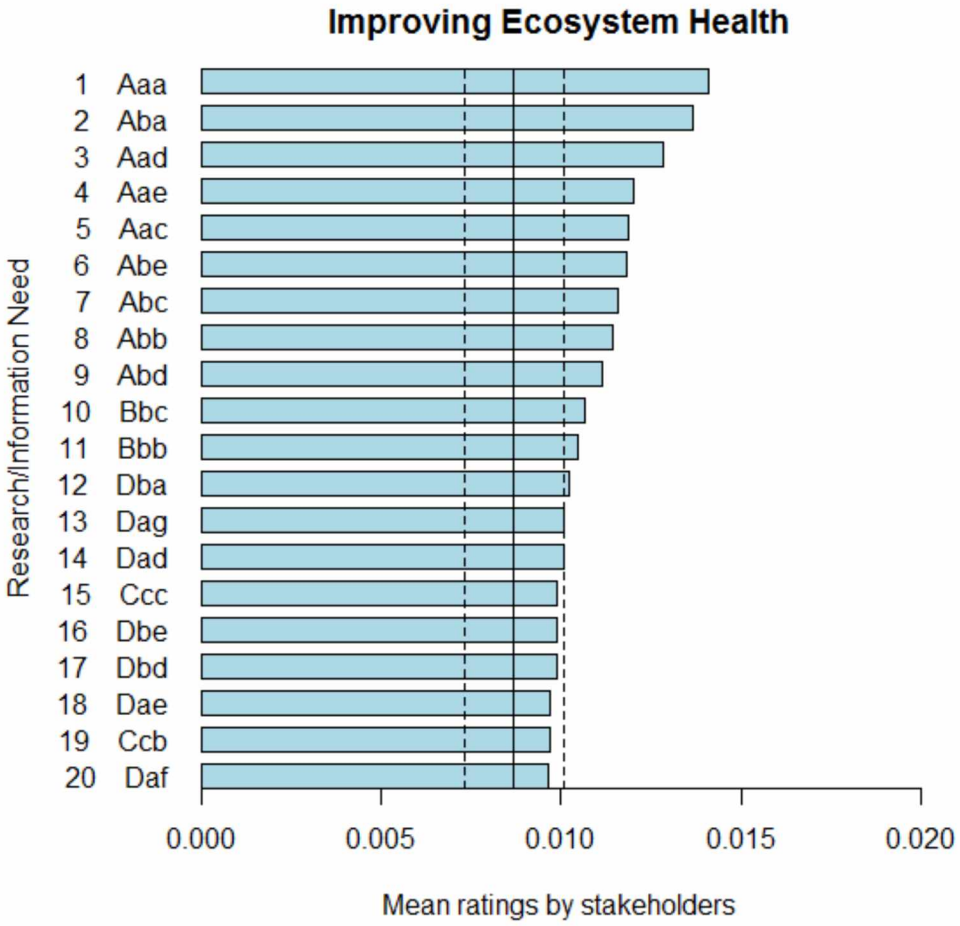

Figure 3. Top twenty research and information needs for *Improving Ecosystem Health* based on mean ratings by the stakeholders. The solid line represents the overall mean; dashed lines represent plus and minus one standard deviation from the mean. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

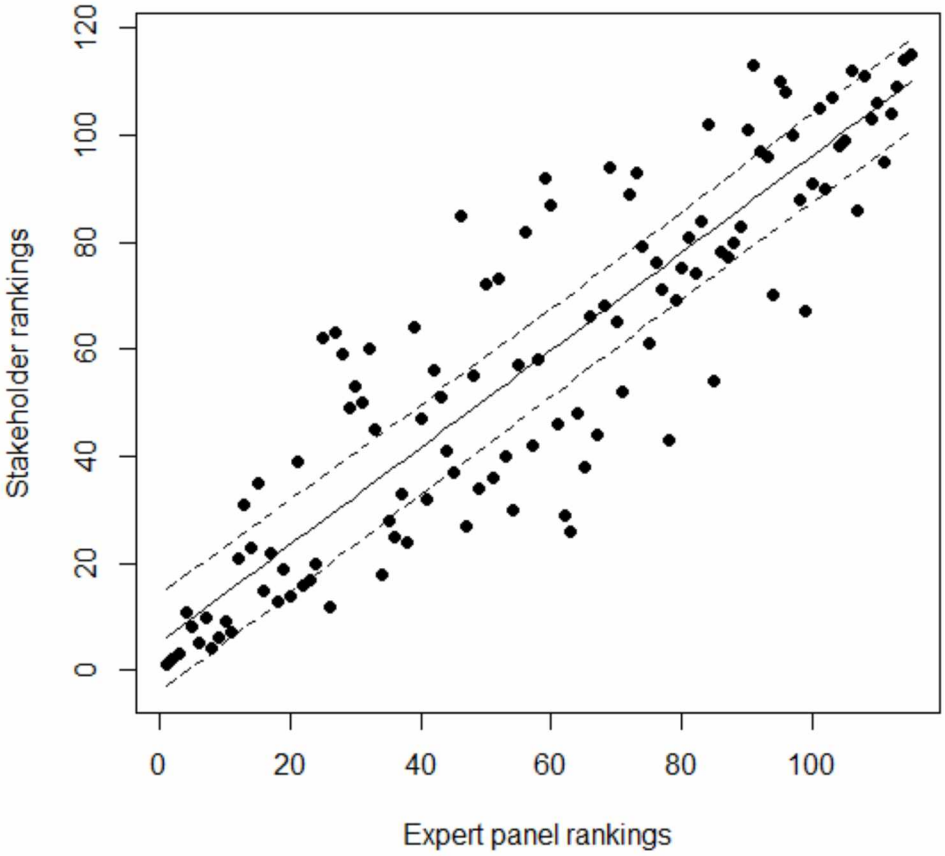

Figure 4. Pairings of ranked research and information needs based on the ratings assigned by stakeholders and mean ratings assigned by expert panelists for *Improving Ecosystem Health* theme. Dashed lines represent bootstrapped estimates of the 95% confidence bounds.

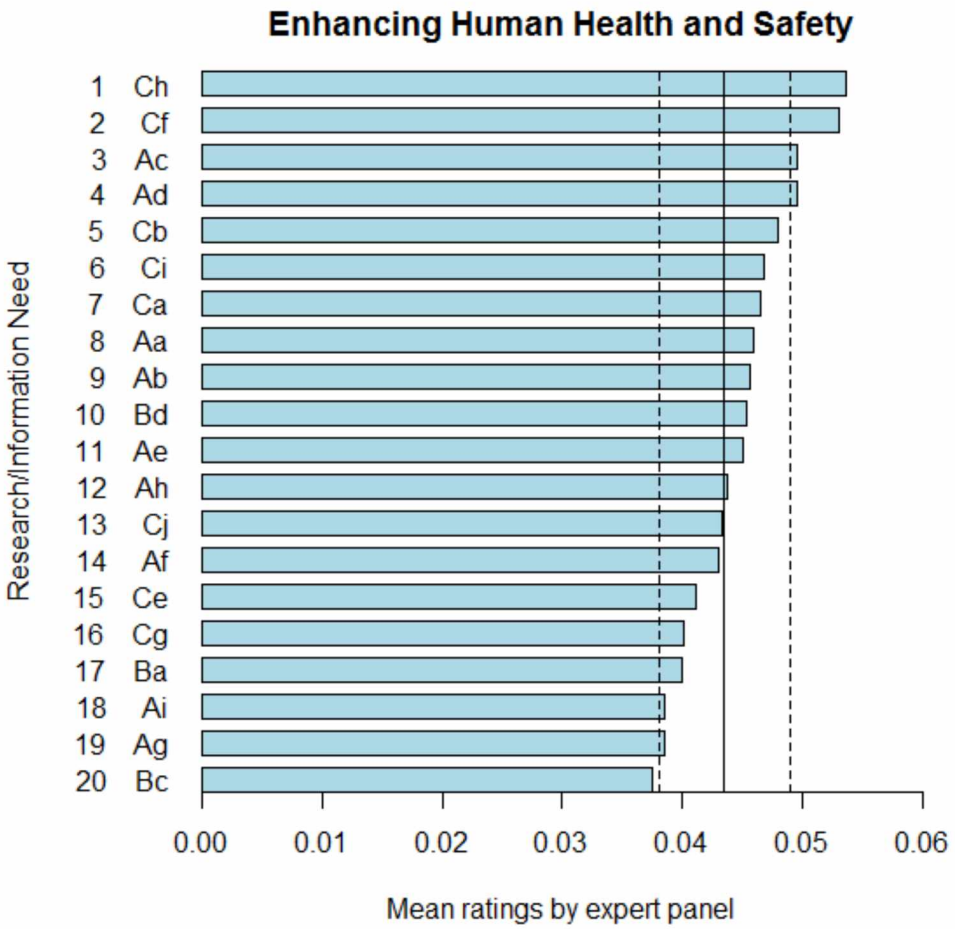

Figure 5. Top twenty research and information needs for *Enhancing Human Health and Safety* based on mean ratings by the expert panel. The solid line represents the overall mean; dashed lines represent plus and minus one standard deviation from the mean. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

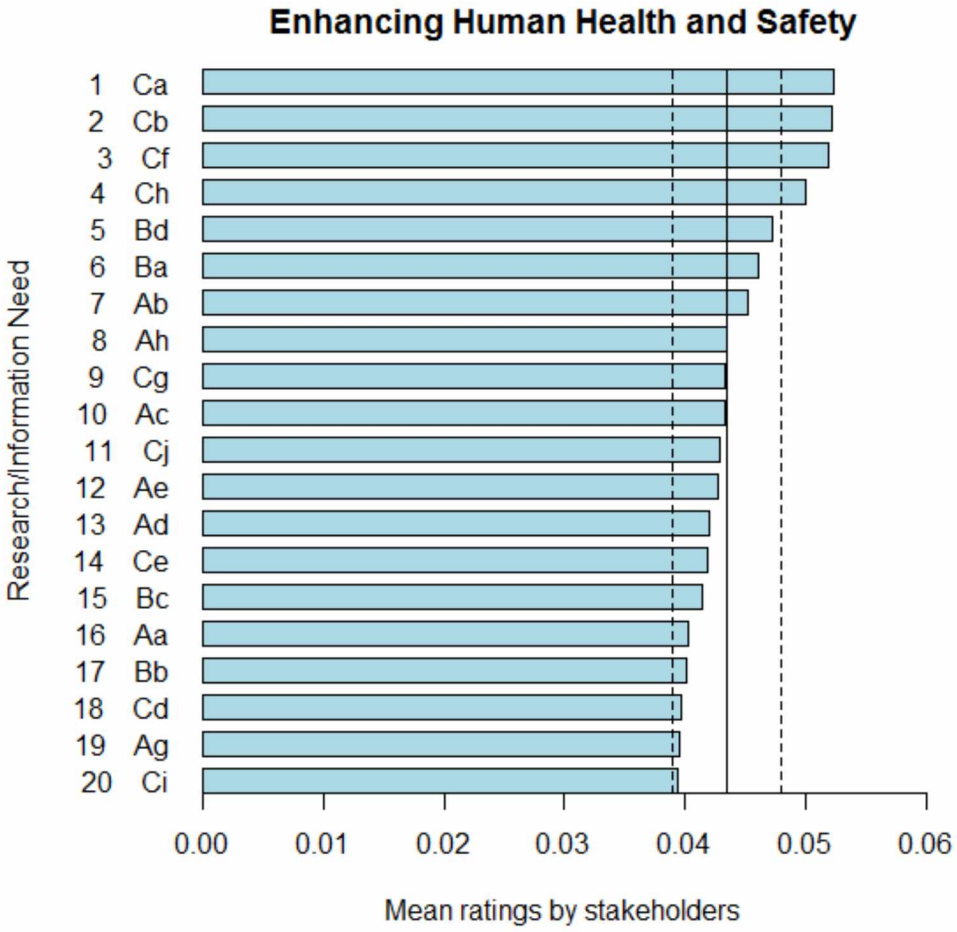

Figure 6. Top twenty research and information needs for *Enhancing Human Health and Safety* based on mean ratings by the stakeholders. The solid line represents the overall mean; dashed lines represent plus and minus one standard deviation from the mean. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

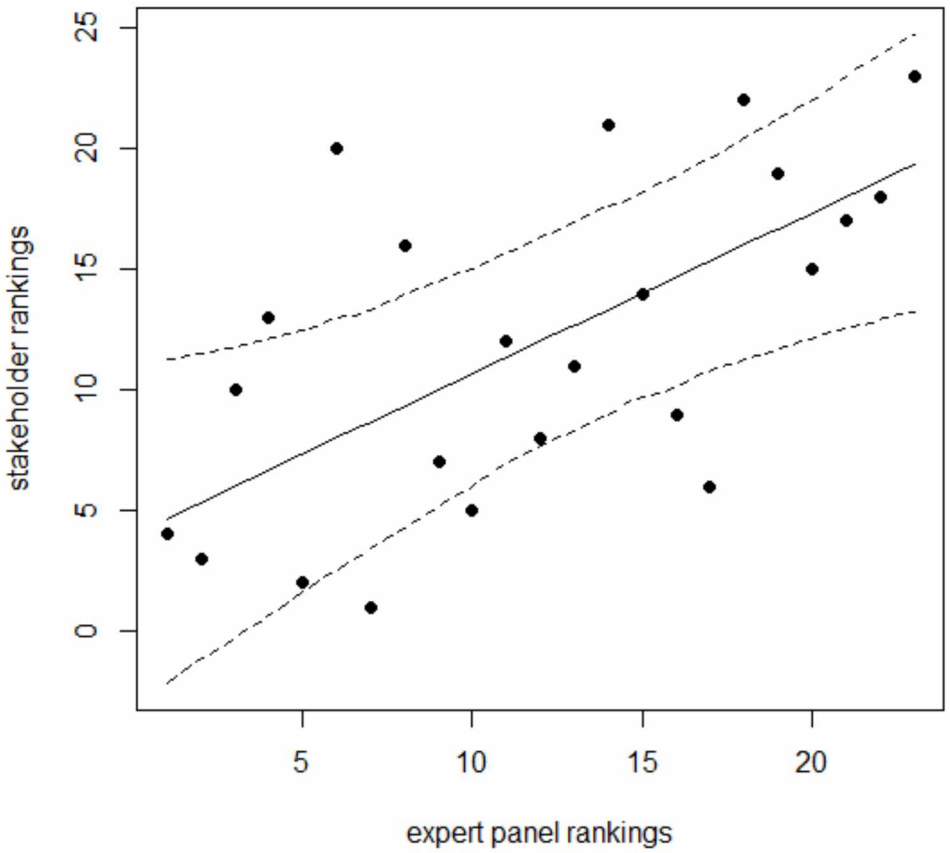

Figure 7. Pairings of ranked research and information needs based on the ratings assigned by stakeholders and mean ratings assigned by expert panelists for *Enhancing Human Health and Safety* theme. Dashed lines represent bootstrapped estimates of the 95% confidence bounds.

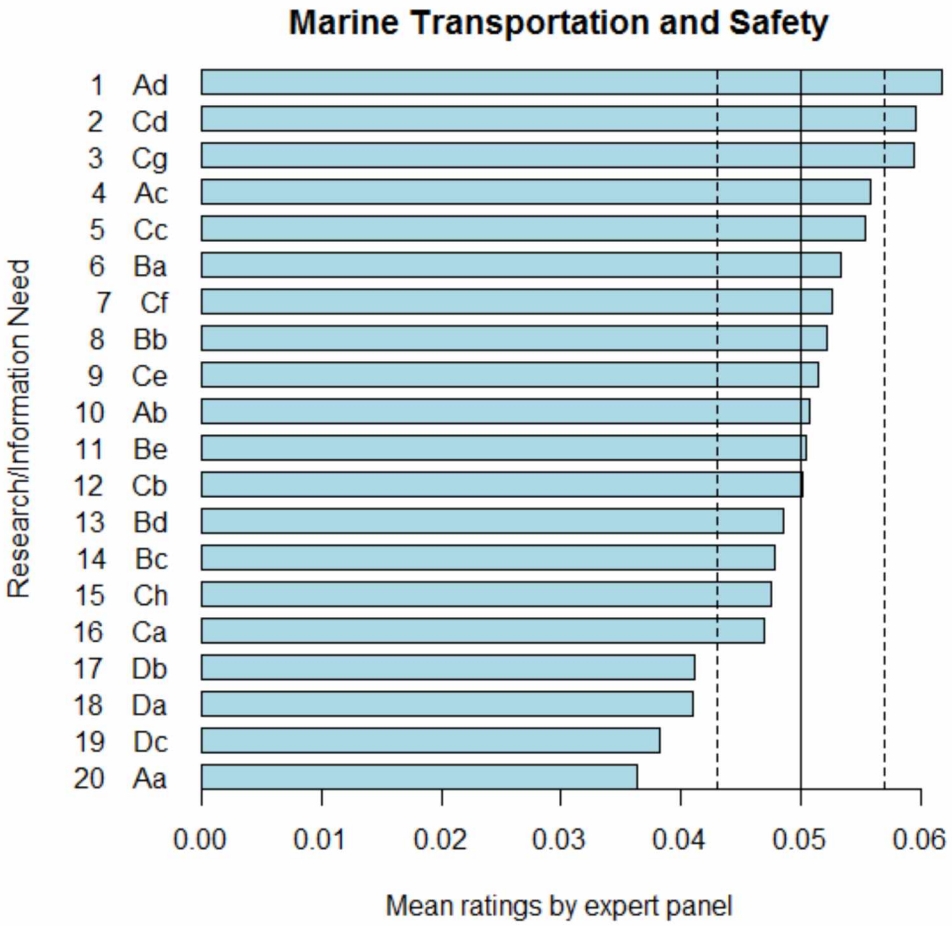

Figure 8. Top twenty research and information needs for *Marine Transportation and Security* based on mean ratings by the expert panel. The solid line represents the overall mean; dashed lines represent plus and minus one standard deviation from the mean. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

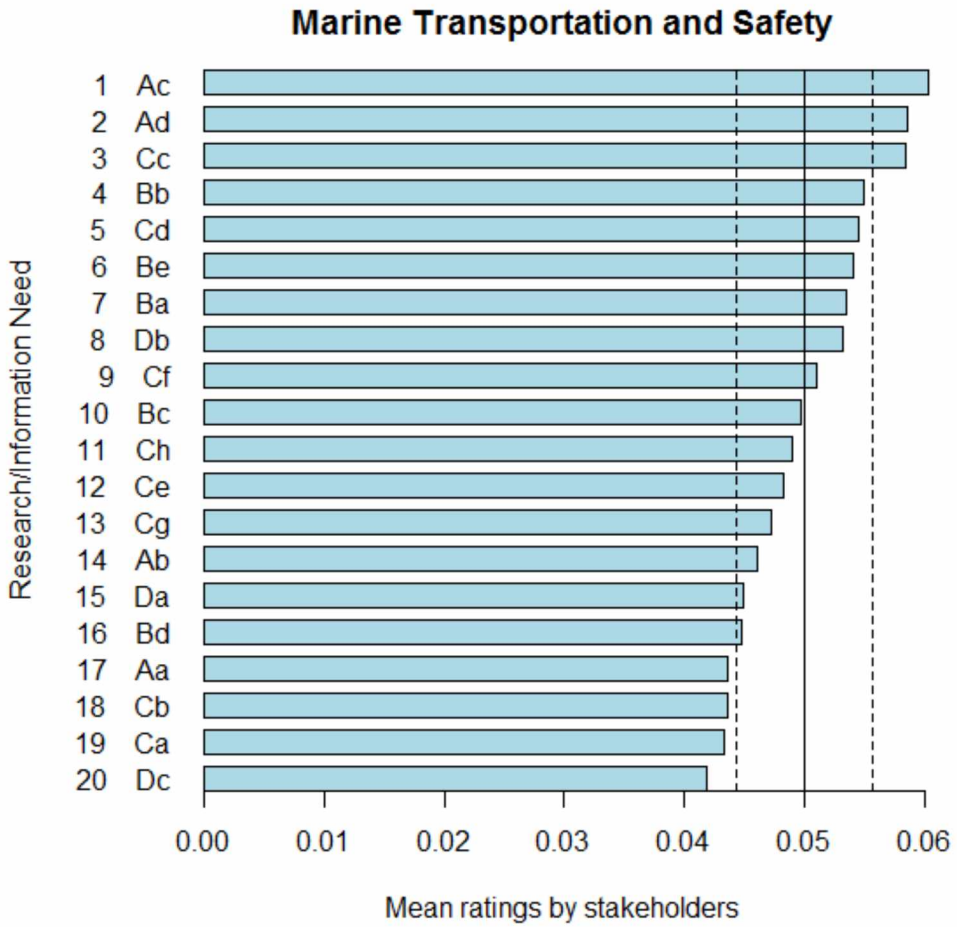

Figure 9. Top twenty research and information needs for *Marine Transportation and Security* based on mean ratings by the stakeholders. The solid line represents the overall mean; dashed lines represent plus and minus one standard deviation from the mean. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).

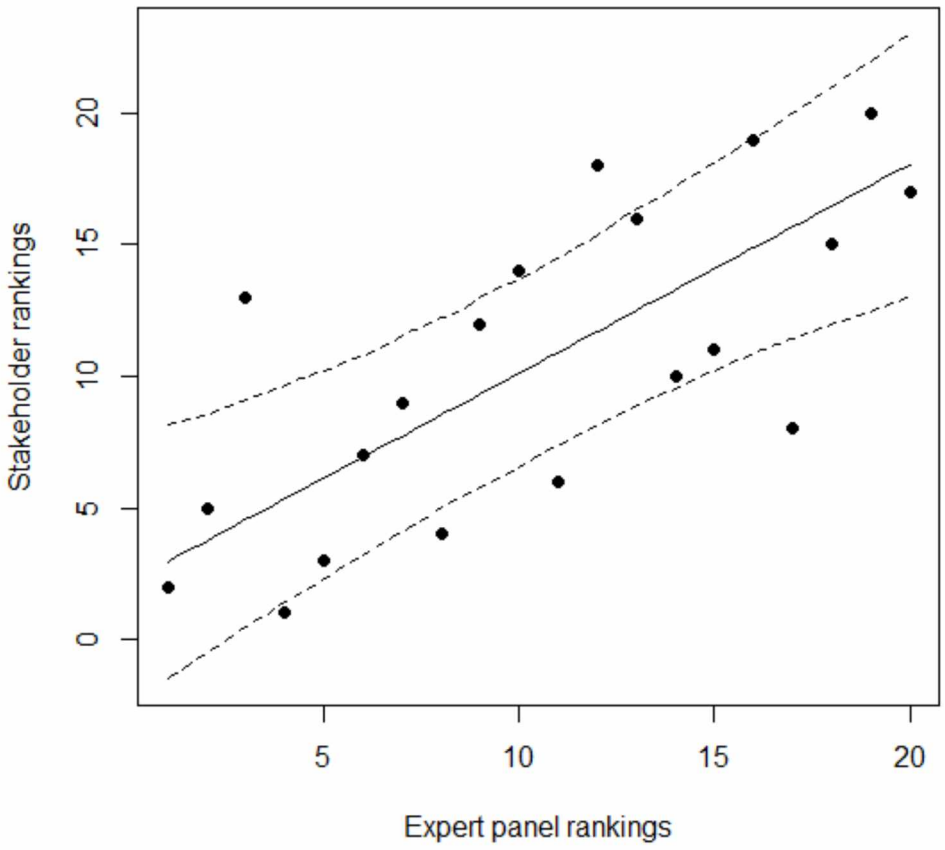

Figure 10. Pairings of ranked research and information needs based on the ratings assigned by stakeholders and mean ratings assigned by expert panelists for *Marine Transportation and Security* theme. Dashed lines represent bootstrapped estimates of the 95% confidence bounds.

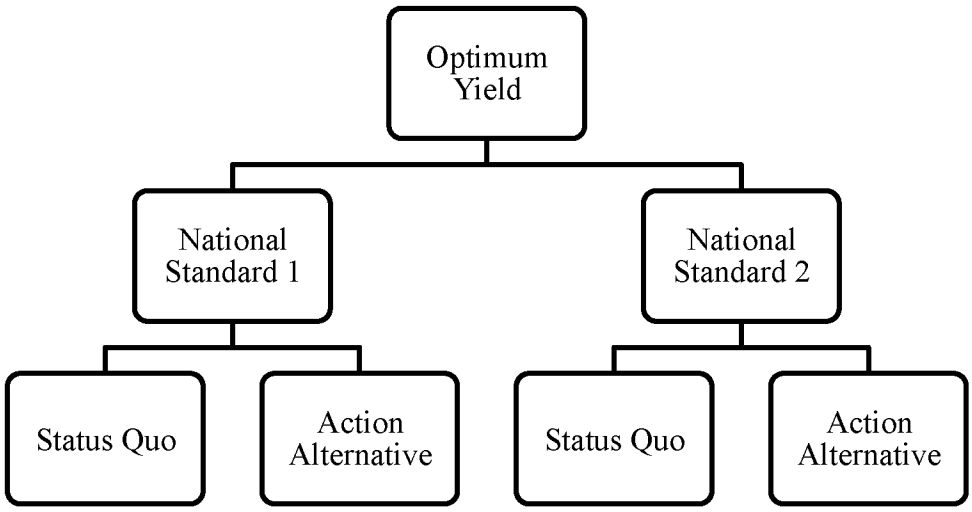

Figure 11. Hierarchy for evaluating action alternatives under the goal of optimum yield, followed by criteria of National Standards and alternatives of the status quo and an action alternative.

Appendix 1. Exemption request granted by the Institutional Review Board for 2010.

UNIVERSITY OF ALASKA FAIRBANKS

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Institutional Review Board

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

October 4, 2010

To:	Keith Criddle, PhD Principal Investigator
From:	University of Alaska Fairbanks IRB
Re:	[192161-1] Aleutian Island Regional Marine Research Plan

Thank you for submitting the New Project referenced below. The submission was handled by Exempt Review. The Office of Research Integrity has determined that the proposed research qualifies for exemption from the requirements of 45 CFR 46. This exemption does not waive the researchers' responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

Title:	Aleutian Island Regional Marine Research Plan
Received:	October 4, 2010
Exemption Category:	2
Effective Date:	October 4, 2010

This action is included on the October 14, 2010 IRB Agenda.

Prior to making substantive changes to the scope of research, research tools, or personnel involved on the project, please contact the Office of Research Integrity to determine whether or not additional review is required. Additional review is not required for small editorial changes to improve the clarity or readability of the research tools or other documents.

Appendix 2. Exemption request granted by the Institutional Review Board for 2011.

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Institutional Review Board

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

August 25, 2011

To:	Keith Criddle, PhD Principal Investigator
From:	University of Alaska Fairbanks IRB
Re:	[192161-2] Aleutian Island Regional Marine Research Plan

Thank you for submitting the Continuing Review/Progress Report referenced below. The submission was handled by Exempt Review. The Office of Research Integrity has determined that the proposed research qualifies for exemption from the requirements of 45 CFR 46. This exemption does not waive the researchers' responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

Title:	Aleutian Island Regional Marine Research Plan
Received:	August 15, 2011
Exemption Category:	2
Effective Date:	August 25, 2011

This action is included on the September 15, 2011 IRB Agenda.

Prior to making substantive changes to the scope of research, research tools, or personnel involved on the project, please contact the Office of Research Integrity to determine whether or not additional review is required. Additional review is not required for small editorial changes to improve the clarity or readability of the research tools or other documents.

Appendix 3. Expert panel hierarchy for *Improving Ecosystem Health*. Research and information needs are organized into categories and sub-categories of related topics; scores reflect expert panel ratings.

Category		Sub-category		Research or information need
0.1239	A. Catalog organisms and identify habitats	0.5126	a. Map abundance and distribution	0.0163 Aaa. Monitor species distribution and abundance indices.
				0.0108 Aab. Identify which species west of 160 have connections to North America and which are more closely connected to Asia.
				0.0119 Aac. Improve identification and classification of invertebrates caught in trawl surveys.
				0.0126 Aad. Study the temporal and spatial distribution and abundance of pollock in Steller sea lion critical habitat.
				0.0118 Aae. Determine the winter distribution of seabirds in the Aleutian Islands.
		0.4874	b. Map habitat	0.0149 Aba. Identify and map the foraging, spawning and nursery habitats of marine species.
				0.0122 Abb. Develop high resolution maps of seafloor geology, morphology and habitat.
				0.0110 Abc. Identify and map the distribution of kelp and other macroalgae.
				0.0110 Abd. Identify Pacific Ocean perch spawning sites.
				0.0113 Abe. Identify Essential Fish Habitat (feeding and spawning habitat) for Atka mackerel.
0.1976	B. Identify indicators, monitor trends & predict changes	0.3294	a. Investigate approaches for monitoring trends	0.0095 Baa. Develop new techniques and technology to interpret ecosystem change.
				0.0092 Bab. Groundtruth satellite and remote sensing data with observations on ecosystem function.
				0.0095 Bac. Evaluate if the use of satellite-based remote sensing can be used with sufficient detail in the Aleutian Islands to be useful.
				0.0095 Bad. Link ecosystem-scale research programs and small scale process studies.
				0.0085 Bae. Determine criteria for establishing research control areas.
				0.0094 Baf. Develop a regional habitat conservation plan that includes monitoring of habitat quality.
				0.0095 Bag. Develop spatial design for long term ecological research stations (where to put them?)
		0.3658	b. Identify indicators	0.0091 Bba. Create an ecosystem report card for oceanographic / biological /economic indicators.
				0.0123 Bbb. Monitor indicators of ecosystem change.
				0.0119 Bbc. Identify and catalogue species in decline and monitor their population shifts.
				0.0106 Bbd. Monitor representative intertidal and nearshore subtidal ecosystems.
				0.0107 Bbe. Use seabird populations as indicators of ecosystem health.
				0.0105 Bbf. Monitor the health and size of eel grass beds.
				0.0071 Bbg. Monitor human health as a measure of ecosystem health.
				0.0000
		0.3048	c. Use local expertise to examine historical evidence of change	0.0084 Bca. Interview elders for local traditional knowledge of ecosystem health and changes over time.
				0.0082 Bcb. Use anthropological and archeological record to characterize environmental history.
				0.0094 Bcc. Study how the relative abundance of species has varied over a long time scale
				0.0083 Bcd. Involve residents in science that goes beyond data collection.
				0.0095 Bce. Determine how ocean carrying capacity has changed / is changing over time.
				0.0076 Bcf. Increase coastal monitoring with an emphasis on stakeholder interests.
				0.0089 Bcg. Increase cooperative with international Arctic researchers and managers.

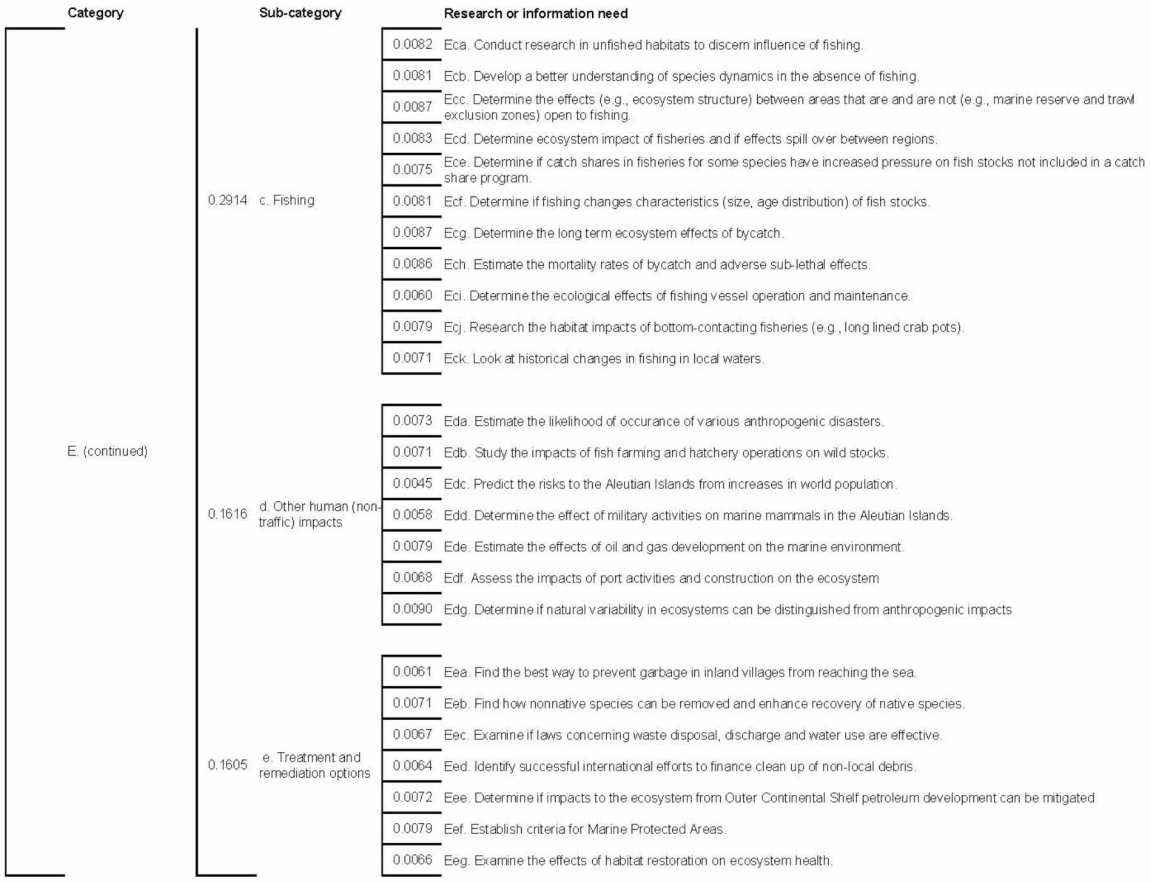
Appendix 3. (Continued)

Category		Sub-category		Research or information need
0.2571	C. Determine the function and inter-relationships of organisms in the ecosystem (life history, food webs, etc.)	0.2614	a. Biological characteristics	0.0082 Caa. Examine the physiological tolerances of species, especially for reproduction.
				0.0086 Cab. Study life history patterns and how they vary in exploited populations.
				0.0095 Cac. Study diets and reproductivity rates of endangered species.
				0.0096 Cad. Determine how apex predator condition varies over time and location.
				0.0087 Cae. Research how surface and subsurface primary production influence salmon run strength.
				0.0080 Caf. Research life cycles of rockfish in nearshore ecosystems.
				0.0082 Cag. Study the early life history information for king crab.
				0.0065 Cah. Gain a better understanding of brown king crab physiology.
		0.1335	b. Movement and distribution	0.0091 Cba. Determine the best scale for evaluating movements of fish and other marine life.
				0.0079 Cbb. Research the movement patterns of nearshore fishes.
				0.0085 Cbc. Study the early life history habitat requirements for king crab.
				0.0088 Cbd. Identify critical habitat for endangered species (e.g., Northern Right Whale).
		0.3054	c. Ecological roles	0.0090 Cca. Study the ecological role of habitats created by cold water sponges and coral.
				0.0103 Ccb. Investigate linkages between marine habitats and resource productivity.
				0.0103 Ccc. Examine the role of marine habitat in fisheries production and ecosystem health.
				0.0087 Ccd. Research the ecological role of rockfish in nearshore ecosystems.
				0.0076 Cce. Determine the winter ecology of nearshore birds, eagles and ravens.
				0.0092 Ccf. Determine the role of benthic macroinvertebrates in the ecosystem.
				0.0097 Ccg. Examine the relationships between target stocks and other species (e.g., seabirds).
				0.0066 Cch. Determine the role of foxes in the coastal terrestrial ecosystem.
				0.0070 Cci. Determine the resource competition between pollock and Pacific ocean perch.
		0.2997	d. Population dynamics	0.0088 Cda. Determine physical and biological factors that drive recruitment variability (including species with episodic recruitment).
				0.0090 Cdb. Determine how to maintain sustainable fisheries with species that have episodic recruitment.
				0.0087 Cdc. Determine why crab, shrimp, and scallop populations have changed.
				0.0080 Cdd. Determine factors that regulate seabird populations.
				0.0091 Cde. Identify causes of large fluctuations in marine mammal populations (e.g. Steller sea lion).
				0.0092 Cdf. Identify causative factors behind decline in sea lions and sea otters.
				0.0087 Cdg. Determine the impact of sea otter decline on nearshore habitat.
				0.0077 Cdh. Need more research on the decline of pollock in the Aleutian Islands.
				0.0079 Cdi. Need more research on the decline of red king crab in the Aleutian Islands.

Appendix 3. (Continued)

Category		Sub-category		Research or information need
0.1219	D. Understand factors that influence & control ecosystem dynamics	0.6080	a. Energy flow: nutrient cycling, trophic/food chain dynamics	0.0092 Daa. Examine interactions between trophic levels of the Aleutian Islands ecosystem.
				0.0084 Dab. Study the importance of salmon as prey for other fish (e.g., pollock and cod).
				0.0079 Dac. Study the importance of salmon as prey for Steller sea lions and fur seals.
				0.0100 Dad. Determine the trophic effects of depleting a target species.
				0.0094 Dae. Determine if predator/prey relationships hinder the recovery of depleted species.
				0.0096 Daf. Determine the importance of forage fish, including capelin, to upper trophic production in the Aleutian Islands.
				0.0103 Dag. Examine the functional roles of commercial species in marine food webs.
				0.0093 Dah. Study the seasonal variation in food web dynamics.
		0.3920	b. Ecosystem linkages	0.0096 Dba. Examine the relationship between deep ocean ecosystems of the Western Aleutian Islands and shallower Bering Sea
				0.0103 Dbb. Study the role of deep passes in limiting the distribution of species.
				0.0087 Dbc. Determine if the Aleutian Islands are a separate ecosystem.
				0.0096 Dbd. Study the linkages between the nearshore habitat and pelagic ecosystems.
				0.0097 Dbe. Examine the links between fish and invertebrate populations in the Aleutian Islands to the open ocean ecosystem and to the Bering Sea and Gulf of Alaska.
0.2995	E. Understand the significance of injurious agents, human activities and other perturbations on the ecosystem and mitigate impacts	0.1640	a. Contaminant sources, paths, and fates	0.0074 Eaa. Research the transport vectors for Asian-origin contaminants.
				0.0076 Eab. Identify toxic waste and debris in the region including origin and magnitude.
				0.0068 Eac. Determine the background level of hydrocarbon contamination.
				0.0076 Ead. Monitor the sea water pollutant levels and water quality.
				0.0062 Eae. Determine if pollution linked to urbanization affects nearshore ecosystems.
				0.0065 Eaf. Determine the contribution of inland garbage to marine pollution.
				0.0070 Eag. Determine the ecological fate of different contaminants.
		0.2226	b. Contaminant impacts on the ecosystem	0.0077 Eba. Determine if contaminant levels in marine biota are increasing or decreasing.
				0.0077 Ebb. Determine the effects of pollutants on the ocean ecosystem.
				0.0071 Ebc. Determine how littoral ecosystems are affected by marine contamination (e.g., marine debris and other forms).
				0.0079 Ebd. Determine how oil spill size, location and frequency impact the ecosystem.
				0.0069 Ebe. Study the impacts of harmful algal blooms on wildlife populations.
				0.0070 Ebf. Determine the environmental effects of fish processing waste discharges.
				0.0067 Ebg. Determine if onshore and offshore fish processors have different impacts on ecosystem health
				0.0076 Ebh. Study the impacts of toxins and disease on marine mammals.
				0.0082 Ebi. Identify invasive species, establish a monitoring program and assess impacts.

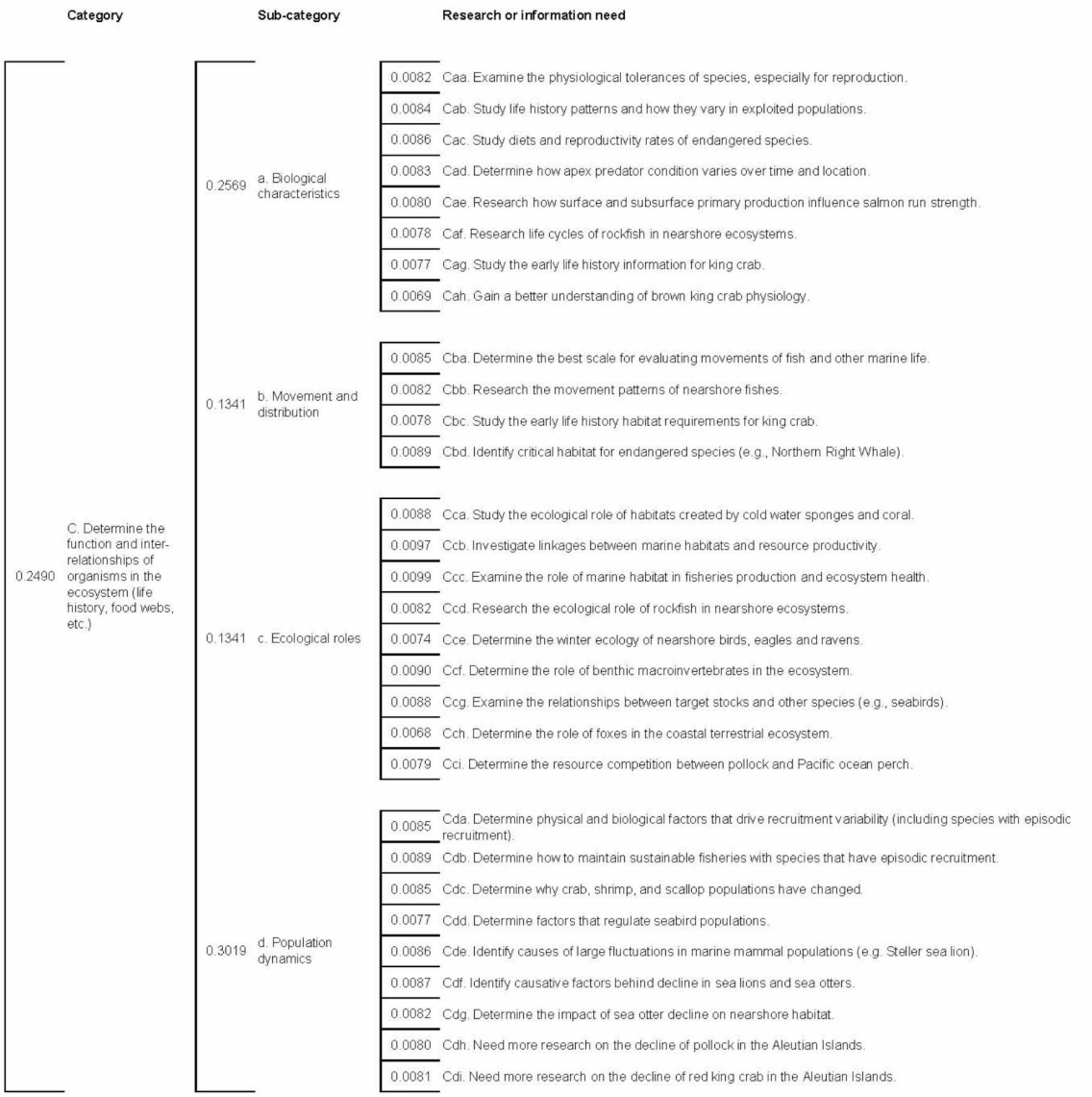
Appendix 3. (Continued)



Appendix 4. Stakeholder hierarchy for *Improving Ecosystem Health*. Research and information needs are organized into categories and sub-categories of related topics; scores reflect public ratings.

Category		Sub-category		Research or information need
0.1200	A. Catalog organisms and identify habitats	0.5035	a. Map abundance and distribution	0.0141 Aaa. Monitor species distribution and abundance indices.
				0.0096 Aab. Identify which species west of 160 have connections to North America and which are more closely connected to Asia.
				0.0119 Aac. Improve identification and classification of invertebrates caught in trawl surveys.
				0.0128 Aad. Study the temporal and spatial distribution and abundance of pollock in Steller sea lion critical habitat.
				0.0120 Aae. Determine the winter distribution of seabirds in the Aleutian Islands.
		0.4965	b. Map habitat	0.0137 Aba. Identify and map the foraging, spawning and nursery habitats of marine species.
				0.0114 Abb. Develop high resolution maps of seafloor geology, morphology and habitat.
				0.0116 Abc. Identify and map the distribution of kelp and other macroalgae.
				0.0111 Abd. Identify Pacific Ocean perch spawning sites.
				0.0118 Abe. Identify Essential Fish Habitat (feeding and spawning habitat) for Atka mackerel.
0.1866	B. Identify indicators, monitor trends & predict changes	0.3141	a. Investigate approaches for monitoring trends	0.0084 Baa. Develop new techniques and technology to interpret ecosystem change.
				0.0083 Bab. Groundtruth satellite and remote sensing data with observations on ecosystem function.
				0.0083 Bac. Evaluate if the use of satellite-based remote sensing can be used with sufficient detail in the Aleutian Islands to be useful.
				0.0086 Bad. Link ecosystem-scale research programs and small scale process studies.
				0.0079 Bae. Determine criteria for establishing research control areas.
				0.0087 Baf. Develop a regional habitat conservation plan that includes monitoring of habitat quality.
				0.0084 Bag. Develop spatial design for long term ecological research stations (where to put them?)
		0.3470	b. Identify indicators	0.0090 Bba. Create an ecosystem report card for oceanographic / biological /economic indicators.
				0.0105 Bbb. Monitor indicators of ecosystem change.
				0.0107 Bbc. Identify and catalogue species in decline and monitor their population shifts.
				0.0096 Bbd. Monitor representative intertidal and nearshore subtidal ecosystems.
				0.0090 Bbe. Use seabird populations as indicators of ecosystem health.
				0.0089 Bbf. Monitor the health and size of eel grass beds.
				0.0071 Bbg. Monitor human health as a measure of ecosystem health.
				0.0000
		0.3389	c. Use local expertise to examine historical evidence of change	0.0092 Bca. Interview elders for local traditional knowledge of ecosystem health and changes over time.
				0.0089 Bcb. Use anthropological and archeological record to characterize environmental history.
				0.0092 Bcc. Study how the relative abundance of species has varied over a long time scale
				0.0094 Bcd. Involve residents in science that goes beyond data collection.
				0.0087 Bce. Determine how ocean carrying capacity has changed / is changing over time.
				0.0086 Bcf. Increase coastal monitoring with an emphasis on stakeholder interests.
				0.0092 Bcg. Increase cooperative with international Arctic researchers and managers.

Appendix 4. (Continued)



Category		Sub-category		Research or information need	
0.2490	C. Determine the function and inter-relationships of organisms in the ecosystem (life history, food webs, etc.)	0.2569	a. Biological characteristics	0.0082	Caa. Examine the physiological tolerances of species, especially for reproduction.
				0.0084	Cab. Study life history patterns and how they vary in exploited populations.
				0.0086	Cac. Study diets and reproductivity rates of endangered species.
				0.0083	Cad. Determine how apex predator condition varies over time and location.
				0.0080	Cae. Research how surface and subsurface primary production influence salmon run strength.
				0.0078	Caf. Research life cycles of rockfish in nearshore ecosystems.
				0.0077	Cag. Study the early life history information for king crab.
				0.0069	Cah. Gain a better understanding of brown king crab physiology.
		0.1341	b. Movement and distribution	0.0085	Cba. Determine the best scale for evaluating movements of fish and other marine life.
				0.0082	Cbb. Research the movement patterns of nearshore fishes.
				0.0078	Cbc. Study the early life history habitat requirements for king crab.
				0.0089	Cbd. Identify critical habitat for endangered species (e.g., Northern Right Whale).
		0.1341	c. Ecological roles	0.0088	Cca. Study the ecological role of habitats created by cold water sponges and coral.
				0.0097	Ccb. Investigate linkages between marine habitats and resource productivity.
				0.0099	Ccc. Examine the role of marine habitat in fisheries production and ecosystem health.
				0.0082	Ccd. Research the ecological role of rockfish in nearshore ecosystems.
				0.0074	Cce. Determine the winter ecology of nearshore birds, eagles and ravens.
				0.0090	Ccf. Determine the role of benthic macroinvertebrates in the ecosystem.
				0.0088	Ccg. Examine the relationships between target stocks and other species (e.g., seabirds).
				0.0068	Cch. Determine the role of foxes in the coastal terrestrial ecosystem.
				0.0079	Cci. Determine the resource competition between pollock and Pacific ocean perch.
		0.3019	d. Population dynamics	0.0085	Cda. Determine physical and biological factors that drive recruitment variability (including species with episodic recruitment).
				0.0089	Cdb. Determine how to maintain sustainable fisheries with species that have episodic recruitment.
				0.0085	Cdc. Determine why crab, shrimp, and scallop populations have changed.
				0.0077	Cdd. Determine factors that regulate seabird populations.
				0.0086	Cde. Identify causes of large fluctuations in marine mammal populations (e.g. Steller sea lion).
				0.0087	Cdf. Identify causative factors behind decline in sea lions and sea otters.
				0.0082	Cdg. Determine the impact of sea otter decline on nearshore habitat.
				0.0080	Cdh. Need more research on the decline of pollock in the Aleutian Islands.
				0.0081	Cdi. Need more research on the decline of red king crab in the Aleutian Islands.

Appendix 4. (Continued)

Category		Sub-category		Research or information need
0.1243	D. Understand factors that influence & control ecosystem dynamics	0.6108	a. Energy flow: nutrient cycling, trophic/food chain dynamics	0.0096 Daa. Examine interactions between trophic levels of the Aleutian Islands ecosystem.
				0.0087 Dab. Study the importance of salmon as prey for other fish (e.g., pollock and cod).
				0.0087 Dac. Study the importance of salmon as prey for Steller sea lions and fur seals.
				0.0101 Dad. Determine the trophic effects of depleting a target species.
				0.0097 Dae. Determine if predator/prey relationships hinder the recovery of depleted species.
				0.0096 Daf. Determine the importance of forage fish, including capelin, to upper trophic production in the Aleutian Islands.
				0.0101 Dag. Examine the functional roles of commercial species in marine food webs.
				0.0094 Dah. Study the seasonal variation in food web dynamics.
		0.3892	b. Ecosystem linkages	0.0102 Dba. Examine the relationship between deep ocean ecosystems of the Western Aleutian Islands and shallower Bering Sea
				0.0096 Dbb. Study the role of deep passes in limiting the distribution of species.
				0.0088 Dbc. Determine if the Aleutian Islands are a separate ecosystem.
				0.0099 Dbd. Study the linkages between the nearshore habitat and pelagic ecosystems.
				0.0099 Dbe. Examine the links between fish and invertebrate populations in the Aleutian Islands to the open ocean ecosystem and to the Bering Sea and Gulf of Alaska.
0.3201	E. Understand the significance of injurious agents, human activities and other perturbations on the ecosystem and mitigate impacts	0.1706	a. Contaminant sources, paths, and fates	0.0074 Eaa. Research the transport vectors for Asian-origin contaminants.
				0.0081 Eab. Identify toxic waste and debris in the region including origin and magnitude.
				0.0078 Eac. Determine the background level of hydrocarbon contamination.
				0.0081 Ead. Monitor the sea water pollutant levels and water quality.
				0.0076 Eae. Determine if pollution linked to urbanization affects nearshore ecosystems.
				0.0073 Eaf. Determine the contribution of inland garbage to marine pollution.
				0.0083 Eag. Determine the ecological fate of different contaminants.
		0.2204	b. Contaminant impacts on the ecosystem	0.0081 Eba. Determine if contaminant levels in marine biota are increasing or decreasing.
				0.0079 Ebb. Determine the effects of pollutants on the ocean ecosystem.
				0.0076 Ebc. Determine how littoral ecosystems are affected by marine contamination (e.g., marine debris and other forms).
				0.0081 Ebd. Determine how oil spill size, location and frequency impact the ecosystem.
				0.0073 Ebe. Study the impacts of harmful algal blooms on wildlife populations.
				0.0078 Ebf. Determine the environmental effects of fish processing waste discharges.
				0.0074 Ebg. Determine if onshore and offshore fish processors have different impacts on ecosystem health
				0.0080 Ebh. Study the impacts of toxins and disease on marine mammals.
				0.0083 Ebi. Identify invasive species, establish a monitoring program and assess impacts.

Appendix 4. (Continued)

Category		Sub-category		Research or information need
E. (continued)	0.2891	c. Fishing	0.0087	Eca. Conduct research in unfished habitats to discern influence of fishing.
			0.0086	Ecb. Develop a better understanding of species dynamics in the absence of fishing.
			0.0091	Ecc. Determine the effects (e.g., ecosystem structure) between areas that are and are not (e.g., marine reserve and trawl exclusion zones) open to fishing.
			0.0087	Ecd. Determine ecosystem impact of fisheries and if effects spill over between regions.
			0.0080	Ece. Determine if catch shares in fisheries for some species have increased pressure on fish stocks not included in a catch share program.
			0.0083	Ecf. Determine if fishing changes characteristics (size, age distribution) of fish stocks.
			0.0089	Ecg. Determine the long term ecosystem effects of bycatch.
			0.0087	Ech. Estimate the mortality rates of bycatch and adverse sub-lethal effects.
			0.0070	Eci. Determine the ecological effects of fishing vessel operation and maintenance.
			0.0084	Ecj. Research the habitat impacts of bottom-contacting fisheries (e.g., long lined crab pots).
			0.0082	Eck. Look at historical changes in fishing in local waters.
	0.1556	d. Other human (non-traffic) impacts	0.0067	Eda. Estimate the likelihood of occurance of various anthropogenic disasters.
			0.0074	Edb. Study the impacts of fish farming and hatchery operations on wild stocks.
			0.0061	Edc. Predict the risks to the Aleutian Islands from increases in world population.
			0.0066	Edd. Determine the effect of military activities on marine mammals in the Aleutian Islands.
			0.0080	Ede. Estimate the effects of oil and gas development on the marine environment.
			0.0071	Edf. Assess the impacts of port activities and construction on the ecosystem
			0.0079	Edg. Determine if natural variability in ecosystems can be distinguished from anthropogenic impacts
	0.1644	e. Treatment and remediation options	0.0073	Eea. Find the best way to prevent garbage in inland villages from reaching the sea.
			0.0069	Eeb. Find how nonnative species can be removed and enhance recovery of native species.
			0.0075	Eec. Examine if laws concerning waste disposal, discharge and water use are effective.
			0.0072	Eed. Identify successful international efforts to finance clean up of non-local debris.
			0.0076	Eee. Determine if impacts to the ecosystem from Outer Continental Shelf petroleum development can be mitigated
			0.0082	Eef. Establish criteria for Marine Protected Areas.
			0.0079	Eeg. Examine the effects of habitat restoration on ecosystem health.

Appendix 5. Expert Panel hierarchy for *Enhancing Human Health and Safety*. Research and information needs are organized into categories and sub-categories of related topics; scores reflect public ratings.

Category		Research or information need	
0.3993	A. Reduce risk to people from contaminants	0.0459	Aa. Develop effective warning systems to alert community members to algal blooms, contaminant spills, and other health hazards.
		0.0456	Ab. Distribute information on safe consumption levels [of contaminants] for local and imported seafoods.
		0.0496	Ac. Determine contaminant loads in commercial and subsistence resources harvested in the region.
		0.0495	Ad. Determine the sources and pathways of the major pollutants in the Aleutian Islands.
		0.0451	Ae. Determine risks and impacts to human health of harmful algal blooms in Aleutian Islands. What are the safest times of year to harvest bivalves.
		0.0430	Af. Locate former U.S. military dump sites and determine levels of toxic materials.
		0.0384	Ag. Investigate conditions (natural or anthropogenic) that trigger harmful algal blooms.
		0.0437	Ah. Improve monitoring to warn the public or to certify specific shellfish harvest areas as safe.
		0.0386	Ai. Determine if ballast water discharges impact the safety of commercial and subsistence seafoods.
0.1599	B. Reduce risk from disease	0.0400	Ba. Implement a human disease surveillance program in the Aleutian Island region.
		0.0371	Bb. Determine the human health risks related to boats coming to port (i.e., disease).
		0.0375	Bc. Determine if changing local diets affect disease incidence.
		0.0453	Bd. Determine what zoonotic diseases are active in foods such as shellfish, fish and marine mammals
0.4408	C. Increase community health and safety	0.0465	Ca. Determine the most serious immediate human health and safety needs in region.
		0.0480	Cb. Promote human health and safety in the Aleutian Island region through education and outreach.
		0.0332	Cc. Develop a protocol for stress-related mental health issues aboard vessels.
		0.0352	Cd. Need to know the nutritional value of fish and shellfish and if it changes over time.
		0.0412	Ce. Need to know how coastal zone development affects health.
		0.0530	Cf. Develop personal, community, and regional emergency response preparedness plans.
		0.0401	Cg. Develop protocols to increase operation safety for government, commerce and military.
		0.0535	Ch. Design search and rescue programs to effectively respond to emergencies throughout Aleutian Area.
		0.0468	Ci. Need to know if the timing of fisheries could be optimized to minimize human casualties associated with fishing.
		0.0433	Cj. Estimate the human health risks of increased shipping traffic.

Appendix 6. Stakeholder hierarchy for *Enhancing Human Health and Safety*. Research and information needs are organized into categories and sub-categories of related topics; scores reflect public ratings.

	Category		Research or information need
0.3752	A. Reduce risk to people from contaminants	0.0403	Aa. Develop effective warning systems to alert community members to algal blooms, contaminant spills, and other health hazards.
		0.0452	Ab. Distribute information on safe consumption levels [of contaminants] for local and imported seafoods.
		0.0432	Ac. Determine contaminant loads in commercial and subsistence resources harvested in the region.
		0.0420	Ad. Determine the sources and pathways of the major pollutants in the Aleutian Islands.
		0.0427	Ae. Determine risks and impacts to human health of harmful algal blooms in Aleutian Islands. What are the safest times of year to harvest bivalves.
		0.0394	Af. Locate former U.S. military dump sites and determine levels of toxic materials.
		0.0395	Ag. Investigate conditions (natural or anthropogenic) that trigger harmful algal blooms.
		0.0435	Ah. Improve monitoring to warn the public or to certify specific shellfish harvest areas as safe.
		0.0394	Ai. Determine if ballast water discharges impact the safety of commercial and subsistence seafoods.
0.1749	B. Reduce risk from disease	0.0461	Ba. Implement a human disease surveillance program in the Aleutian Island region.
		0.0402	Bb. Determine the human health risks related to boats coming to port (i.e., disease).
		0.0414	Bc. Determine if changing local diets affect disease incidence.
		0.0473	Bd. Determine what zoonotic diseases are active in foods such as shellfish, fish and marine mammals
0.4499	C. Increase community health and safety	0.0523	Ca. Determine the most serious immediate human health and safety needs in region.
		0.0521	Cb. Promote human health and safety in the Aleutian Island region through education and outreach.
		0.0365	Cc. Develop a protocol for stress-related mental health issues aboard vessels.
		0.0396	Cd. Need to know the nutritional value of fish and shellfish and if it changes over time.
		0.0419	Ce. Need to know how coastal zone development affects health.
		0.0519	Cf. Develop personal, community, and regional emergency response preparedness plans.
		0.0433	Cg. Develop protocols to increase operation safety for government, commerce and military.
		0.0500	Ch. Design search and rescue programs to effectively respond to emergencies throughout Aleutian Area.
		0.0394	Ci. Need to know if the timing of fisheries could be optimized to minimize human casualties associated with fishing.
		0.0429	Cj. Estimate the human health risks of increased shipping traffic.

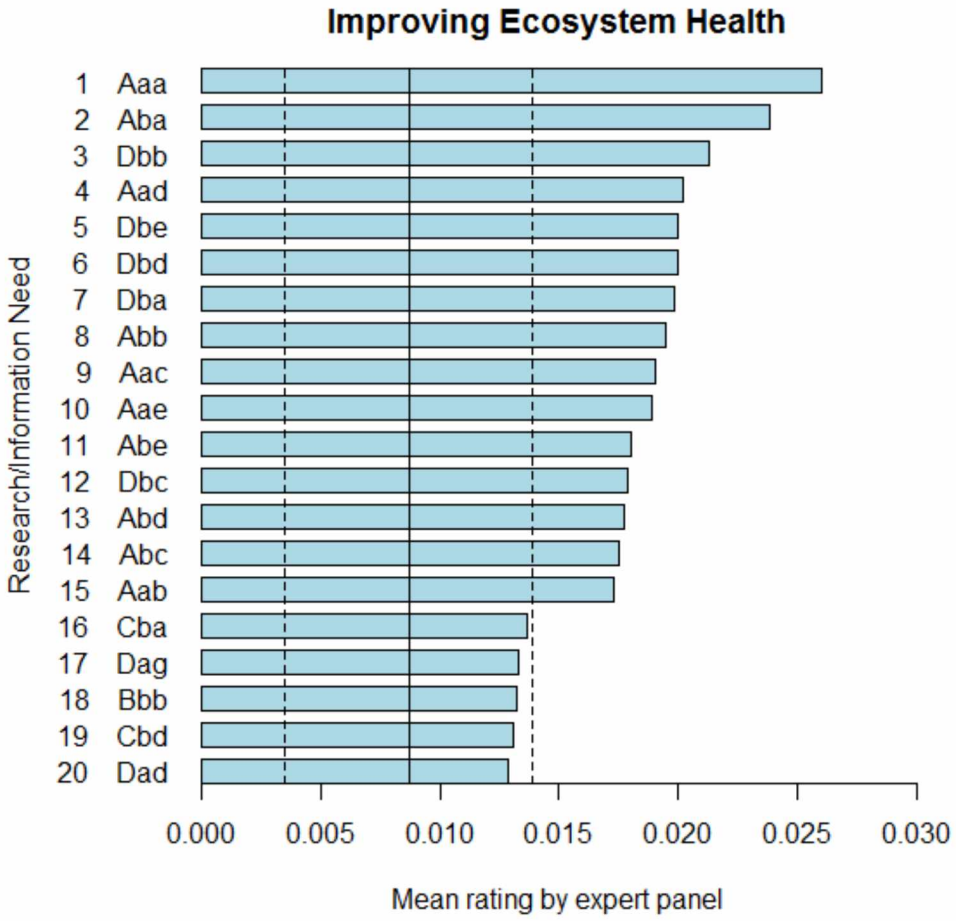
Appendix 7. Expert panel hierarchy for *Marine Transportation and Security*. Research and information needs are organized into categories of related topics; scores reflect expert panel ratings.

	Category		Research or information need
0.2046	A. Improve response to marine vessel disasters and emergencies	0.0364	Aa. Determine incentives to attract private investment in infrastructure needed for emergency response.
		0.0507	Ab. Develop shipping traffic maps for anticipated changes in shipping and fishing activity.
		0.0558	Ac. Determine if current infrastructure (tugs, booms, refueling, marine services, etc.) is sufficient to respond to shipping accidents and oil spills.
		0.0618	Ad. Develop a regional oil spill response plan.
0.2522	B. Foster efficient and safe marine traffic to reduce risk of harm from marine vessel disasters and emergencies	0.0533	Ba. Examine methods to control shipping (e.g., require VMS or emergency transponders and sailing plans on all transiting vessels).
		0.0522	Bb. Determine if island passes are bottlenecks that warrant additional shipping regulation (e.g., designated shipping lanes, tug boat escorts).
		0.0477	Bc. Regularly update bathymetric maps of the seafloor and currents models through the Aleutian passes to increase transportation safety.
		0.0485	Bd. Improve reporting and forecasting of sea conditions.
		0.0505	Be. Provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels.
0.4229	C. Assess and minimize negative environmental impacts of marine traffic	0.0469	Ca. Estimate the frequency and causes of collisions with whales with increased shipping.
		0.0501	Cb. Assess marine shipping impacts with attention to anticipated effects of changes in lanes and routes.
		0.0553	Cc. Determine how traffic related to anticipated Outer Continental Shelf (OCS) exploration and development will impact the Aleutian Islands
		0.0596	Cd. Identify transportation routes that cross sensitive habitats.
		0.0514	Ce. Determine disturbance impacts to marine life and habitat in areas of occasional vs. steady marine traffic.
		0.0526	Cf. Examine alternatives for managing environmental impacts of shipping (e.g., traffic lanes, no transit zones around critical habitat, speed limits).
		0.0595	Cg. Assess the risks and impacts of ballast water and small fuel discharges on the environment.
		0.0475	Ch. Map habitats and the effects of shipping, fishing and marine debris on those habitats.
0.1203	D. Assess the socioeconomic impacts of marine traffic	0.0410	Da. Determine if changes in mandatory landing locations for fisheries in the region will reduce transportation costs.
		0.0411	Db. Determine if an inter-island marine transportation system is feasible and will facilitate the transportation of goods and people.
		0.0382	Dc. Determine the socioeconomic impacts of increased transit shipping.

Appendix 8. Stakeholder hierarchy for *Marine Transportation and Security*. Research and information needs are organized into categories of related topics; scores reflect public ratings.

	Category		Research or information need
0.2085	A. Improve response to marine vessel disasters and emergencies	0.0435	Aa. Determine incentives to attract private investment in infrastructure needed for emergency response.
		0.0461	Ab. Develop shipping traffic maps for anticipated changes in shipping and fishing activity.
		0.0603	Ac. Determine if current infrastructure (tugs, booms, refueling, marine services, etc.) is sufficient to respond to shipping accidents and oil spills.
		0.0585	Ad. Develop a regional oil spill response plan.
0.2568	B. Foster efficient and safe marine traffic to reduce risk of harm from marine vessel disasters and emergencies	0.0535	Ba. Examine methods to control shipping (e.g., require VMS or emergency transponders and sailing plans on all transiting vessels).
		0.0549	Bb. Determine if island passes are bottlenecks that warrant additional shipping regulation (e.g., designated shipping lanes, tug boat escorts).
		0.0496	Bc. Regularly update bathymetric maps of the seafloor and currents models through the Aleutian passes to increase transportation safety.
		0.0448	Bd. Improve reporting and forecasting of sea conditions.
		0.0541	Be. Provide training/education for vessel operators and communities for risks involved in response to fuel/oil spills and downed vessels.
0.3950	C. Assess and minimize negative environmental impacts of marine traffic	0.0432	Ca. Estimate the frequency and causes of collisions with whales with increased shipping.
		0.0435	Cb. Assess marine shipping impacts with attention to anticipated effects of changes in lanes and routes.
		0.0584	Cc. Determine how traffic related to anticipated Outer Continental Shelf (OCS) exploration and development will impact the Aleutian Islands
		0.0544	Cd. Identify transportation routes that cross sensitive habitats.
		0.0483	Ce. Determine disturbance impacts to marine life and habitat in areas of occasional vs. steady marine traffic.
		0.0510	Cf. Examine alternatives for managing environmental impacts of shipping (e.g., traffic lanes, no transit zones around critical habitat, speed limits).
		0.0472	Cg. Assess the risks and impacts of ballast water and small fuel discharges on the environment.
		0.0490	Ch. Map habitats and the effects of shipping, fishing and marine debris on those habitats.
0.1398	D. Assess the socioeconomic impacts of marine traffic	0.0449	Da. Determine if changes in mandatory landing locations for fisheries in the region will reduce transportation costs.
		0.0531	Db. Determine if an inter-island marine transportation system is feasible and will facilitate the transportation of goods and people.
		0.0418	Dc. Determine the socioeconomic impacts of increased transit shipping.

Appendix 9. Unbalanced top twenty research and information needs for *Improving Ecosystem Health* based on mean ratings by the expert panel. The solid line represents the overall mean; dashed lines represent plus and minus one standard deviation from the mean. Lettered codes represent the category (first letter), sub-category (second letter) and research and information need (third letter).



Appendix 10. Unbalanced pairings of ranked research and information needs based on the ratings assigned by stakeholders and mean ratings assigned by expert panelists for Improving Ecosystem Health theme. Dashed lines represent bootstrapped estimates of the 95% confidence bounds.